# RURAL WATER SUPPLIES
# AND THEIR PURIFICATION·

BY

ALEXANDER CRUIKSHANK HOUSTON,

M.B., D.Sc., F.R.S.Ed.

*Director of Water Examination, Metropolitan Water Board*

ILLUSTRATED

THIS LITTLE BOOK IS, WITH PERMISSION,

RESPECTFULLY. DEDICATED BY THE WRITER TO

SIR WILLIAM OSLER, BART., M.D., F.R.S., F.R.C.P.(LOND.),

●REGIUS PROFESSOR OF MEDICINE, OXFORD UNIVERSITY,

IN APPRECIATION OF

HIS INVALUABLE SERVICES TO MEDICINE,

HIS HIGH LITERARY GIFTS AND HIS UNAFFECTED

MANNERS AND SUNNY GENEROUS DISPOSITION;

QUALITIES WHICH ATTRACT HIS MANY FRIENDS

AS FORCIBLY AS OPEN SPACES, GREEN FIELDS

AND PLEASANT WATERS APPEAL TO LOVERS OF

THE COUNTRY.
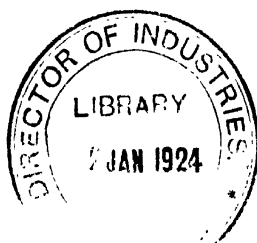
# PREFACE.

THE kindly reception given to the writer'
previous books, "Studies in Water Supply
(Messrs. Macmillan and Co., 1913), and " River
as Sources of Water Supply" (Messrs. John Bale
Sons and Danielsson, Ltd., 1917), has led him t
try and fulfil a want which has long been felt b
rural dwellers.

Despite the enormous improvements in ou
public water supplies, not only as regards quality
and quantity of water, but in respect of it
availability to isolated communities, there remains
a large, but scattered population, whose only source
of a primary necessity of life is the utilization of
rain-water, or the water from shallow wells, neigh-
bouring rivers, streams, or lakes. These private
isolated supplies, lying outside the direct control of
Public Authorities, are frequently polluted and a
source of potential danger to health. It is to be
feared that in many of these cases there is a regret-
table disregard of possible consequences, and
although a minority of individuals remains anxious
to remedy existing evils, adequate knowledge of

how best to proceed is often lacking. Even those who are usually careless as regards water supply may soon learn wisdom, or prove amenable to friendly advice, but unfortunately their would-be advisers are themselves often at a loss what course to suggest.

The writer has always been glad to give his advice freely to professional men—for example, clergymen and doctors in the country concerned about the welfare, as regards water supply, of their parishioners and patients. In answering these appeals for help, which are often of a pressing and sometimes of a pathetic character, the writer has often felt how great the gulf is between theory and practice, how hopeless it is to attempt, within the limits of ordinary correspondence, to deal satisfactorily with so complex a subject, and how useless it is to give references to books which do not contain the exact kind of information really required.

A life-long experience of water questions has left the writer in the position of a learner, and in his spare time he has endeavoured to acquire a more practical knowledge of rural requirements. In trying to teach others, the would-be teacher speedily learns how much has to be self-learnt, but the writer's purpose will have been served, if, in this little book, he can usefully hand on to others the outcome of some of his own experiences

The future of this country holds possibilities which can only be gauged by guess work. One effect of the War may be to increase enormously the number of people who like to do things well, and to decrease correspondingly the number of those who prefer to let things "slide." There has been un-questionably a great awakening, and amidst the excitement and sadness of a colossal war one sees everywhere signs of quickened interest. Beyond all doubt, in the ordinary affairs of life, there is a growing tendency to learn and work and succeed, not merely from recognition that ignorance and idleness and failure may spell disaster, but because, let psychologists explain it as they may, some influence is at work impelling people to adopt a saner outlook on life, which was not felt, or in much less degree, in pre-war days. One direction in which a change is noticeable is in the growing appreciation of the value of sanitary science, and in this connection the question of water supply will receive its full share of attention. The writer is of opinion, as already suggested, that in the future it will become, to a progressive extent, a pleasure and not a burden to do things efficiently (e.g., to take a homely illustration, cooking). So also is he optimistic enough to believe that "scamping" and ignorance in connection with water supply will largely disappear. It is true that pessimists declare that when the War is over there will be a rapid reversion to the old somewhat careless ways of

living. Others, however, hope and believe that the tendency will be quite the other way. Much depends on how we are taught to regard the ordinary affairs of life. Education, discipline, example, if not mere suggestion, can render our daily tasks almost pleasurably exciting. Speaking irrespective of any party the writer ventures·to· think that a little more imagination (the greatest gift on earth) on the part of our rulers is needed. Many hours are spent daily, and spent well, in cooking operations. Surely it is worth while to devote a few minutes, say in the morning and evening, to purifying water for domestic use.

Again, no one knows to what extent our mode of life may change. *At heart we are all country-folk*, and after the War there may be an unprecedented rush for the peaceful country, 'stimulated, perhaps, by the standardization of houses, more equitable terms for the purchase of houses and land, war weariness, shattered nerves, reduced incomes, difficulty of soldiers reverting to town life after their experiences at the Front, successful results of allotment gardening, tariff on imported foodstuffs, improved railway facilities for the conveyance of market produce and recognition of the value of co-operation, revived love of Nature, alarm at the falling birth-rate (for which town life is partly responsible), increasing distrust of over-centralization, simpler standards of living and dislike

of ostentation, growth of democratic (in the best
sense of the word) ideas, reversion to more primi-
tive (but perhaps saner) ideals, and other factors.
Should these events come to pass, rural water
supplies will become of enormous importance, and
means of purifying contaminated water will be
eagerly sought after. For it is hardly conceivable
that a large, new and widely-scattered rural popula-
tion can be supplied economically now (possibly
not for many years to come) from the existing or
even contemplated public sources of water supply.
Moreover, this book will have failed in its object
if it does not convince the reader that almost any
water supply can be purified to any standard of
safety required.

It would be a grave mistake to suppose that the
writer is wavering in his allegiance to public water
supplies—quite the contrary is the case—but com-
plete belief in responsible control does not imply dis-
belief in making the best of existing circumstances.

The writer feels that some words of explanation
are needed to his potential readers. The actual
expert will perhaps find little in these pages by way
of instruction, unless, indeed, the writer's long
experience as a bacteriologist and epidemiologist
may here and there prove to be of some slight use.
Next come those who by their capabilities and
training (not necessarily technical) are admirably
qualified, prospectively, if not immediately, to help

themselves, and others, as regards the safety of water
supplies. These may possibly find this little book
a useful stepping-stone to further progress. Lastly,
but most importantly, come those who have grown
a little rusty, those who are inexperienced but
zealous to learn, and those who, whatever their
limitations may appear to be, are determined·to·
overcome all obstacles. These are the readers to
whom the writer specially makes his appeal.

A moment's reflection will suggest the wide circle
of country dwellers liable to be affected by non-
public water supplies. The dreamy philosopher,·
the ascetic, the man of science, the millionaire, the
sportsman, the invalid, the clergyman, the doctor,
the farmer, the rich and the poor.

There is another aspect of the case· which the
writer feels deserves recognition.

The principles which underlie the choice and
treatment of water supplies, be they public or
private, are very much the same, and the writer in
studying rural requirements has widened consider-
ably the scope of his own knowledge of the subject
of water supply generally.

Is it too much to hope then that the more
fortunate and more numerous consumers of publicly
controlled water supplies may find in this treatise
some point of importance to stimulate their interest
in a subject which may be as old as the hills, but

which still possesses unexhausted fields of possibili-
ties? Even the partial realization of such a hope
would far more than repay the writer for the time
and labour he has devoted to the study of rural
water supplies.

Perhaps the best years of the writer's life have
been spent in the service of the Metropolitan Water
Board; his work has been rendered additionally
pleasant for the reason that although primarily con-
cerned with London's Water Supply, the policy of
his Board has always been in the direction of
improving knowledge of water supplies gener-
ally. Not less grateful is the writer to the members
of his staff, whose active co-operation and valuable
help have been of so pleasant and intimate a
character that he welcomes success more for their
sakes than for his own.

Since writing these notes, the author has read in
the *Morning Post* of November 9, 1917, a letter
from Lord Sydenham, entitled "Home Settlement
for Ex-Service Men."

The following extracts are of interest :—

"It has been said that few of our sailors and
soldiers will wish to settle on the land, and that
during the period of reconstruction after the War
there will be an immense demand for labour. We
cannot be certain as to what the extent and the

nature of the labour demanded will be. Nor can
we assume that the men themselves will necessarily
be willing to fall in completely with preconceived
ideas. They have fought for our freedom, and
saved the Empire from disaster. We must consider
the effect that the War has had upon them. Their
nerve-shaking experiences, and their altered outlook
on life, are bound to make a certain number of them
welcome the conditions of life on the land, instead
of in urban surroundings. We must ensure that
the necessary opportunities are provided."

"The Royal Colonial Institute has during the
past two years issued and circulated some hundreds
of thousands of leaflets in the endeavour to let our
sailors and soldiers know what opportunities there
are for them at Home and Overseas. The inquiries
arising from these leaflets are extremely interesting,
because they show that so far the number of men
desiring to settle at home is equal to, if not greater
than, that of those who wish to emigrate to the
Dominions. This fact alone proves the urgent
need for immediate action on the part of the
Government."

In conclusion, the writer ventures to hope that
this book may be of some little use in post-war
settlement, so far as rural water supplies are con-
cerned. (*See* offer of help on p. 128.)

*January*, 1918.                    A. C. HOUSTON.

# CONTENTS.

The book is arranged as follows :—

The first three Chapters are devoted to the study of rain-water. All the chief methods for sterilizing and purifying waters are here dealt with in detail, and it is assumed that the reader will master their contents as the subsequent Chapters IV. and V., (well-waters, springs, rivers, brooks and lake-water) deal chiefly with generalizations.

In Chapters VI. and VII. the results of actual experiments are considered, and in Chapter VIII. a description of the apparatus required is given.

Next comes some miscellaneous information (nature of chemicals, symbols, atomic weights, weights and measures, conversions) notes on lime and chlorine, ·cost of chemicals, &c., which may be useful to the non-expert reader.

In advance of each Chapter there is a summary of contents, and at the end a few concluding remarks.

The index is at the end of the book.

*The non-expert reader should not be turned aside by the amount of technical matter necessarily included in this book. References to the concluding notes at the end of each Chapter (pp. 12, 34, 46, 56, 67, 88, 101, 113) and to Miscellaneous Information (p. 114) will simplify things considerably. See also concluding remarks on p. 128.*

# ILLUSTRATIONS.

The writer is greatly indebted to Mr. Kershaw for permission to quote his views on the utilisation of rain-water (with plan of rain-water tank, p. 125), and to Messrs. Baird and Tatlock (scientific instrument makers, laboratory fitters, chemical dealers, &c.), 14, Cross Street, Hatton Garden, E.C. 1, for the loan of blocks in connection with Figures 2, 4, 5, 6, 7, 8, 12, and 14.

# RURAL WATER SUPPLIES AND THEIR PURIFICATION.

## CHAPTER I.

### RAIN - WATER.[1]

First Report (1916) of the Committee formed (1912) for the Investigation of Atmospheric Pollution—Composition of normal air—Gaseous and solid impurities of the atmosphere—Results of analyses of rain-water—Questions of taste—Physical appearances and chemical composition of rain-water—Health considerations—Sterilization and purification of rain-water—**Concluding remarks (p. 12).**

$\mathbf{A}$ S a result of a conference of delegates of municipal authorities and others held in connection with the Smoke Abatement Exhibition in 1912, a Committee was formed for the Investigation of Atmospheric Pollution. The Committee's first

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[1] The writer feels that he is justified in placing this source of water supply first, because it may be the sole refuge of dwellers in certain rural areas where there is neither a public water supply nor reasonable hope of providing at a non-prohibitive cost a private supply (superficial or deep). To this must be added the fact that a rain-water supply, although often impure and most difficult to render palatable, is practically free from the possibility of human fæcal pollution. (*See*, however, qualifying remarks on p. 10.) Most of our

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report[1] was published in 1916 and contains a great deal of useful information, bearing directly or indirectly, on the quality of rain-water.

The following table, taken from the report. shows the composition of normal air :—

TABLE I.—COMPOSITION OF NORMAL AIR.

| Oxygen ... | ... | ... | ... | ... | ... | 20·94 |
| Nitrogen... | ... | ... | ... | ... | ... | 78·09 |
| Argon ... | ... | ... | ... | ... | ... | 0·94 |
| Carbon dioxide ... | ... | ... | ... | ... | 0·03 |
| Helium, krypton, neon, &c. ... | ... | ... | traces |

100·00

Unfortunately, falling rain is not only affected by the presence of these gases, but also by the gaseous and solid pollutions of the atmosphere resulting from animal and vegetable life and the manifold operations of mankind.

Coastguard stations have rain-water supplies for domestic use. From a British point of view, one of the most interesting water supplies in the world is that of Gibraltar. For non-potable purposes (e.g., flushing) a brackish water is used. There is also an emergency distilling plant for furnishing, if required, a potable supply from sea-water, but the principal drinking supply is from the rain, which apparently is partly collected from a cemented rock surface, and also from corrugated iron sheets laid on sandy slopes. The rain falling on these surfaces is led into underground storage reservoirs, the locality of which is, of course, necessarily kept secret. (*See* "Water Supply," by Dr. W. P. Mason. John Wiley and Sons.) Information as regards the Bermuda rain-water supply will be found on p. 124.

[1] *Lancet*, February 26, 1916. Offices of Committee, 47, Victoria Street, Westminster, London, S.W.

The Committee give the results of the analysis of the solid matters intercepted by the ventilator filters of a large institution in London :—

TABLE II.—ANALYSIS OF SOLID MATTERS FROM VENTILATOR FILTERS.

| | | | | |
|---|---|---|---|---|
| Sodium chloride ... | ... | ... | ... | trace |
| Calcium carbonate | ... | ... | ... | 2·17 per cent. |
| Ferric oxide ... | ... | ... | ... | 2·44 „ |
| Calcium sulphate ... | ... | ... | ... | 5·09 „ |
| Alumina ... ... | ... | ... | ... | 8·34 „ |
| Magnesium carbonate | ... | ... | ... | 0·33 „ |
| Sand ... ... | ... | ... | ... | 37·99 „ |
| Carbon ... ... | ... | ... | ... | 35·48 „ |
| Ammonium sulphate | ... | ... | ... | 5·77 „ |
| Tar (extracted by $CS_2$) ... | ... | ... | 1·49 „ |
| Fibrous matter ... | ... | ... | ... | 0·95 „ |
| | | | | 100·05 „ |

The large proportion of carbon, together with sticky tarry matter, explains why the surface of all·solids, both inside and outside buildings, are coated with filthy sooty material in large towns. Not less important in relation to destructive effect on stone buildings is the presence of sulphur compounds.

One of the chief sources of these suspended impurities in the air is the imperfect combustion of bituminous coal, and the analyses of samples of the sooty matters produced are given in the report. (*See* Table III.)

· These are the matters which cling to the walls of the chimneys and also pass in the form of smoke · into the atmosphere accompanied by many noxious

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gases, e.g., formaldehyde, sulphuretted hydrogen, carbonic oxide, carbonic dioxide, sulphur oxides, ammonia, &c.

TABLE III.—ANALYSES OF SOOTY MATTERS.

|  | Sample No. 1 | Sample No. 2 |
|---|---|---|
| $SO_3$ ... ... ... | 6·2 per cent. ... | 5·8 per cent. |
| $H_2O$ ... ... ... | 4·4 ,, ... | 4·0 ,, |
| CaO ... ... ... | 1·4 ,, ... | 2·5 ,, |
| $Fe_2O_3$ ... ... | 2·2 ,, ... | 2·5 ,, |
| Cl ... ... ... | 7·7 ,, ... | 7·9 ,, |
| Ether extract (tar) ... | 28·6 ,, ... | 17·7 ,, |
| $NH_3$ (combined) ... | 4·7 ,, ... | 3·8 ,, |
| Other constituents ... | 44·8 ,, ... | 55·8 : ,, |

The oxides of sulphur and ammonia, whether existing separately as gases or combined to form the soluble solid ammonium sulphate, appear to exercise a most destructive action on buildings.

The report sets forth very clearly the advantages of gas and electric heating and cooking stoves over coal fires, so far as atmospheric pollution is concerned.

"The products of combustion from a gas fire consist mainly of $CO_2$ and water vapour, together with a minute quantity of sulphur oxides. There is a total absence of those tarry and carbonaceous substances that are produced by the use of raw coal, and as the sulphur is so exceedingly small in amount the gaseous method of heating is comparatively innocuous. As regards heating capacity, a coal fire consuming 21 lb. of coal per day would be

about equal to a gas fire consuming 200 cubic feet of gas per day, but whereas the coal would evolve about 1,500 grains of sulphur in various forms, as well as tar, carbon, &c., already alluded to, the gas would contribute only 50 or 60 grains of sulphur in the form of sulphur oxides. Electric stoves do not evolve products of combustion, and therefore their use also tends to a cleaner air.

"Apart from the polluting effect of the 20 to 30 lb. of sulphur for each ton of coal consumed, it is regrettable that this valuable material should be wasted. Its total amount must be huge. The Committee recognizes that much of this waste of material is avoided when coal is utilized in the gasworks."

In view of what has been said, it is small wonder that rain-water is apt to be seriously contaminated, especially near large towns and manufacturing centres. Rain literally washes the air, and so inevitably contains, either in solution or suspension, many impure substances which are really foreign to a non-vitiated atmosphere.

On the other hand, the reader must preserve a sense of proportion and remember that the impurities which contaminate rain-water (collected over a *clean* area) are drawn into the respiratory passages with every breath we take, and yet town dwellers seem to thrive on the respiratory "capture" (potentially) of substances which mixed with or dissolved in rain-water appear to be of almost poisonous significance.

No doubt the respiratory tract is a purifying and filtering agency, but so, to some extent, is the alimentary tract. At all events, the amount of rain-water we require for drinking purposes is small and the contained impurities relatively slight when compared with the huge volume of air which we breathe and the aggregate amount of apparently · deleterious substances liable to be absorbed or retained in the process of respiration. Of course, when rain is collected from areas which concentrate, so to speak, past atmospheric pollutions and add to them other contaminations, which are not truly of aerial origin, the case may be different.

The Committee in seeking to investigate the pollution of the atmosphere adopted the expedient of collecting, at a number of centres, the total rainfall for each month of the year in a standard circular gauge vessel of four square feet superficial area, and submitting the liquid to special analysis. ·

The results are expressed as metric tons (2,205 lb.) per square kilometre (about 250 acres).

There may be many advantages in expressing the results in this way, but it would be a great convenience if, as well, they were expressed as parts per 100,000 or grains per gallon of *rain-water*. As the volume of water collected is always measured, this could readily be done.

A useful table of the deposit per acre per month is given on p. 31 of the report.

It should be noted that the nine columns are not

independent of each other. The tar, carbonaceous
matter and ash come under the heading of insoluble
matter. The loss on ignition and ash refer to
the soluble matter, and included in this are the
sulphates, chlorine, and ammonia.

TABLE IV.—Deposit per Acre per Month (Rain-water).

| | Tar | Carbonaceous other than tar | Ash | Loss on ignition | Ash | Total solids | SO₄ | Cl | NH₃ |
|---|---|---|---|---|---|---|---|---|---|
| | lb. | lb. | lb. | lb. | lb. | lb. | lb. | lb. | lb. |
| Class A ... (The Malvern type) | 0·23 | 4·5 | 9 | 3·4 | 6·8 | 23 | 4·5 | 1·4 | 0·23 |
| Class B ... (The Ravenscourt Park or Cheadle type) | 0·9 | 18 | 36 | 13·5 | 27 | 90 | 18 | 5·4 | 0·9 |
| Class C ... (The Liverpool or Embankment Gardens type) | 1·8 | 36 | 72 | 27 | 54 | 180 | 36 | 10·8 | 1·8 |
| Class D ... (The Oldham type) | Over 2·25 | Over 45 | Over 90 | Over 34 | Over 68 | Over 225 | Over 45 | Over 14 | Over 2·3 |

One inch of rain per acre is equal to 22,622 gallons
(about 101 tons, say 100 tons), and 2 to 3 inches
of rainfall per month is a good average figure to
take. Adopting 2·5 inches, 250 tons, or 2,240
× 250 = 560,000 lb. of rain-water contain the
number of lbs. of the constituents given in the
table. On this basis the relatively pure Malvern
type of rain-water yields, in parts per 100,000 and
grains per gallon, the following results :—

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TABLE V.—ANALYSIS RELATIVELY PURE RAIN WATER.

| | Parts per 100,000 | | Grains per gallon |
|---|---|---|---|
| *Insoluble matter:—* | | | |
| Tar ... ... ... ... | 0·041 | ... | 0·0287 |
| Carbonaceous (other than tar) | 0·8 | ... | 0·56 |
| Ash ... ... ... ... | 1·6 | ... | 1·12 |
| *Soluble matter:—* | | | |
| Loss on ignition ... ... | 0·6 | ... | 0·42 |
| Ash ... ... ... ... | 1·21 | ... | 0·847 |
| *Total solids* ... ... ... | 4·1 | ... | 2·87 |
| *Included in soluble matter:—* | | | |
| Sulphur as SO₄ ... ... | 0·8 | ... | 0·56 |
| Chlorine as Cl ... ... | 0·25 | ... | 0·175 |
| Ammonia as NH ... ... | 0·041 | ... | 0·0287 |

For present purposes the Malvern (comparatively pure) type is best chosen as an example, because in the vicinity of towns Public Water Supplies are nearly always available, and in such cases it is quite unnecessary, if not indefensible, to use rain-water for drinking purposes.

The gauge vessel used by the Committee is enamelled, and there is a device to safeguard it, as far as possible, against the "droppings" of birds.

When rain is collected from roofs, the roof surfaces, and more especially the gutters, harbour all sorts of accumulated filth (e.g., manure, dust, grit, decaying vegetation, "droppings" of birds and small animals, &c.).

It follows that the first "washings," after the cessation of a period of fine weather, are apt to be very foul, and "separators" (*see* p. 126) are often provided which reject this portion and allow of

Fig. 1. Shows the suspended matter in 0·5 c.c. of a sample of rain-water collected in London ( 50 diam.).

the collection only of rain-water after this pre-
liminary scouring has taken place.

In considering the possibility of using rain-
water for potable purposes, regard must be had to
questions of taste, chemical composition, physical
qualities, and, most important of all, considerations
of health.[1]

Speaking generally, there is nothing in the
chemical composition of rain-water to preclude its
use for drinking purposes apart from its physical
qualities and taste.

As regards taste, even pure rain-water is apt to
have a flat, insipid taste, and impure samples are
so objectionable as almost to create feelings of
nausea (see p. 63).

The physical appearances of rain-water are often
most uninviting. It is frequently highly coloured
and contains much suspended matter.

The analysis of a town collected sample of rain-
water gave results (in grains per gallon) as
follows :—

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[1] The writer feels that he labours under the disadvantage
of trying to appeal both to the expert and non-expert reader.
For the former, advice is hardly needed unless indeed the
writer's experience as an epidemiologist and bacteriologist
may prove to be of some little value. As regards the latter,
an endeavour will be made to show that the ordinary man of
affairs is quite competent to safeguard the purity of any
ordinary rural water supply, although he may have at the
outset to seek expert help.

TABLE VI.—ANALYSIS OF TOWN RAIN-WATER.

| | | | | |
|---|---|---|---|---|
| Ammoniacal nitrogen ... ... ... ... | 0·14 |
| Albuminoid nitrogen ... ... ... ... | 0·015 |
| Chlorine ... ... ... ... ... ... | 0·45 |
| Oxygen absorbed from permanganate ... | 0·22 |
| Total hardness ... ... ... ... ... | 3·7 |
| Colour (m.m. brown, 2-ft. tube) ... ... | 160 |

The high figures for ammoniacal nitrogen, oxidizable matter and colour are especially noteworthy.

It is of interest to give for comparative purposes the corresponding figures (grains per gallon) for the *raw* Thames and Thames-derived *filtered* waters for the ten-year period ended March 31, 1916.

TABLE VII.—ANALYSIS OF *Raw* THAMES AND THAMES *Filtered* WATER.

| | *Raw* Thames water | | Thames-derived *filtered* water |
|---|---|---|---|
| Ammoniacal nitrogen ... ... | 0·005 | ... | 0·0002 |
| Albuminoid nitrogen ... ... ... | 0·011 | ... | 0·0043 |
| Chlorine ... ... ... ... | 1·2 | ... | 1·15 |
| Oxygen absorbed from permanganate | 0·147 | ... | 0·059 |
| Total hardness ... ... ... | 16·3 | ... | 15·6 |
| Colour (m.m. brown, 2-ft. tube) ... | 71 | ... | 19 |

From a health point of view, rain-water has the advantage that it is practically free from the possibility of *human* excremental pollution. That is, of course, excluding those cases where the rain-water is stored in pervious underground tanks, unfavourably situated as regards drains, cesspools, and other sources of dangerous contamination. On the other hand, roof collected rain-water may be,

contaminated by the "droppings" of birds, the excreta of rats, mice, and other lower animals, and a multitude of flies, insects, &c. Some diseases of the lower animals are communicable to man, and it would seem not unwise to regard unpurified rain-water as potentially unsafe, if not actually dangerous.

The first thing to consider then is how rain-water can be best sterilized, and, secondly, how it can be so purified as to be physically free from objection as regards colour, suspended matter and taste. It is assumed in what follows that the rain-water has been collected in bulk in storage cisterns, tanks or butts and all that is needed is to periodically purify such proportion of the bulk quantity as will meet the daily requirements of the household. It would obviously be out of place to encroach on the domain of the architect or the engineer and describe methods of separating the first "washings" and the best means of collecting and storing rain-water in bulk (see, however, notes under Miscellaneous Information, p. 126). It is, however, taken for granted that the expert in these matters has provided against the possibility of the stored rain-water becoming contaminated from outside sources. For example, a pervious underground tank, badly situated as regards external sources of pollution, should, as already suggested, at once be condemned.

In conclusion, the chief points to be noted are as follows :—

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Putting on one side the dirty discoloured appearances of rain-water, its unpleasant taste, and the presence of sulphur compounds and tarry matters, there is nothing chemically objectionable in its use for drinking purposes.

On the other hand, if the mode of collection of rain-water is open to criticism (as it usually is), many undesirable impurities may be added to its normal composition.

Bacteriologically it is potentially unsafe, or at least open to suspicion, as, under ordinary conditions, it is liable to be polluted with excrementitious matter. On the other hand, it is practically free from the possibility of the worst kind of contamination, namely, the discharges of human beings (*see*, however, qualifying remarks on p. 10).

Assuming it to be possible to remove, or reduce satisfactorily, the taste,[1] suspended matter and colour, and to kill all harmful microbes without leaving in the water any noxious substance, rain-water is perfectly safe for drinking purposes.

The methods of rendering rain-water safe and palatable will next be described.

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[1] The question of taste is fully considered on p. 63. The non-technical reader may find it convenient to concentrate attention on this page (12) and pass over lightly the preceding technical paragraphs.

# CHAPTER II.

## RAIN-WATER— (Continued).

## EXCESS LIME METHOD.[1]

Rain-water is very soft and normally contains
so few substances capable of combining with lime
that the use of this substance as a sterilizing agent
is specially attractive in view of its cheap and
innocuous character.   In the doses about to be
recommended, a lime-treated water has no taste
(due to lime) and the use of lime is "hallowed by
. precedent." From a purely scientific point of view,
these matters may seem to be relatively un-

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[1] For fuller information the reader is referred to p. 78 of
the author's little book " Rivers as Sources of Water Supply "
(Messrs. John Bale, Sons and Danielsson, Oxford House,
·83-91, Great Titchfield Street, Oxford Street, London, W.1).

important, yet the average person may consider that they dominate the whole position.

The first thing to determine is how much of the lime is used up and therefore rendered non-bactericidal by the dissolved carbonic .acid, bicarbonates, magnesium salts, &c., in the rain-water. It is well worth acquiring this knowledge (despite its technical character) because once it has been mastered all lime sterilization processes become matters of extreme simplicity and certainty.

Add 20 c.c. of standard lime water (1 c.c. = 0·001 gramme CaO)[1] to 700 c.c. rain-water (= 2 grains per gallon) in a stoppered bottle, shake and allow any precipitate formed to settle.

Rinse out a small flask and 100 c.c. (cubic centimetres) measuring cylinder (*see* figs. 2 and 3) respectively with the settled liquid.

In all chemical operations "rinsing" is of vital importance, and if the point is not pressed hereafter, it is assumed that this warning will not be neglected.

Measure out 70 c.c. (cubic centimetres) of the settled liquid, pour it into the flask, and add a few drops of phenol phthalein solution (*see* p. 115); the liquid ought to turn bright pink. If it does not do

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[1] Any first class firm of chemical dealers employing well-trained chemists can supply the standard or other solutions or chemicals mentioned in this treatise. On p. 114 will be found a few elementary notes on the various chemicals, materials, &c., mentioned in this little work. No apology is needed to the expert if the non-expert reader finds them of some little use.

so, repeat the experiment using more lime water (in.measured amount).

It should perhaps be explained here that standard solutions are made up on the metric gramme and



FIG. 2.



c.c.

80

70

60

*(about ⅕ th)*   *(about full size)*
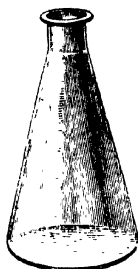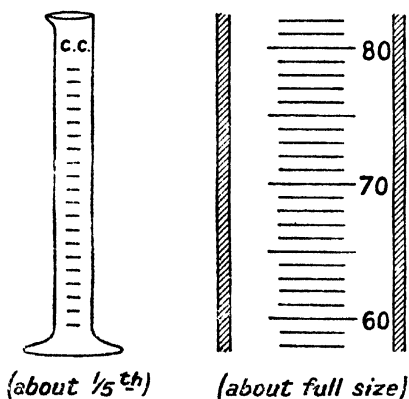
FIG. 3.—100 c.c. measuring cylinder.

cubic centimetre basis. If one uses 100 c.c. (100,000 milligrammes) of water for analysis the results read as parts per 100,000 parts ; if 70 c.c.

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(70,000 milligrammes) the results read as grains per gallon, because a gallon weighs 70,000 grains.

Rinse out a burette (*see* fig. 4) fixed in a burette stand (*see* fig. 5) with a little standard sulphuric acid (1 c.c. = 0·001 gramme CaO) and fill up to the 0·0 c.c. mark with the acid.
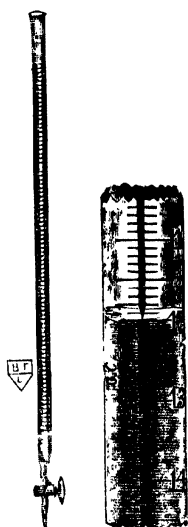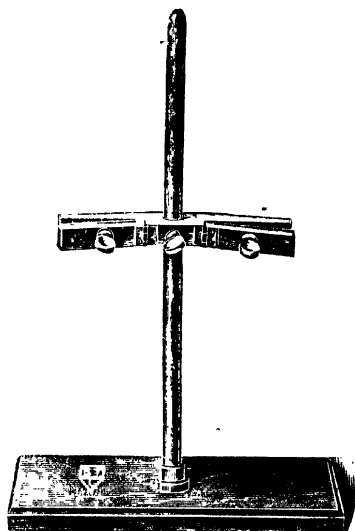


FIG. 4.          FIG. 5.

Add the acid, a few drops at a time, to the contents of the flask until the pink colour just disappears on shaking, and then take the reading (say, 4 c.c. of acid used).

Next add a very few drops of methyl orange solution (*see* p. 115) and proceed with the titration until the yellow colour begins to change to pink. This

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requires a little practice, and it is desirable for comparative purposes to add the same amount of methyl orange to 70 c.c. of rain-water contained in a separate flask and compare the tints during titration. Now take the final reading, that is, the *total* number of cubic centimetres of acid used up (say, 7 c.c. ·required altogether). Then multiply the first phenol phthalein reading by 2, and subtract the total methyl orange reading from it: $4 \times 2 \quad 8 - 7 = 1$. Now as ·2 were added (*see* p. 14) and 1 remains, the CaO used up (i.e., rendered inoperative) is equal to 1 grain per gallon and this must be allowed for in calculating the dose of lime required for sterilization purposes. For example, if the dose for sterilization purposes is 3 grains, then 4 grains would be required for each gallon. Should the phenol phthalein reading doubled be less than the total reading (methyl orange), this shows that there is no excess of lime (CaO), and the operation must be repeated ·and more lime-water used.

If it is proposed to remove the permanent hardness (due to sulphates, not affected by boiling) as well as to sterilize the rain-water, the sulphates present should be determined. This, however, involves precipitation with baric chloride (using and therefore wasting at least 1,000 c.c. of rain-water) and the very accurate weighing of the precipitate of barium sulphate produced. Another and simpler

* For further information *see* table on p. 55.

plan is to estimate the permanent hardness by means of the soap test and allow 1·06 (anhydrous) or 2·86 (crystals) grains of sodium carbonate for every degree of hardness. The procedure is as follows :—

Measure out (fig. 3) 70 c.c. of the rain-water, pour the liquid into a small flask (fig. 2), and boil until the volume of the water has been reduced about one-half. Add 25 c.c. of previously boiled and cooled distilled water and transfer contents to a measuring cylinder (fig. 3) and, when cool, add more distilled water so as to bring the volume of liquid back to the original 70 c.c. Transfer this to a small bottle (fig. 6) and from a burette (figs. 4 and 5) run in a few drops of standard soap solution (1 c.c. = 1 grain per gallon $CaCO_3$) at intervals, shaking vigorously after each addition until a lather which remains "unbroken" for a few minutes is obtained. The number of cubic centimetres of soap used represents the degrees of permanent hardness (grains per gallon) of the water. Suppose 4 c.c. are needed, then $4 \times 2·86 = 11·44$ grains of soda crystals per gallon are required. Although a useful chemical exercise the determination of the permanent hardness with a view to its removal is usually not a matter of great importance.

FIG. 6.

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Let it be supposed that 10 gallons is the amount of water to be dealt with.

Ten gallons of rain-water are transferred from the rain-water tanks or butts into a suitable vessel.

In Chapter VIII. will be found a description of the vessel recommended, but the writer feels that his purpose will have failed if it does not stimulate others to improve greatly on the tentative suggestions here offered.

The water should be strained through wire gauze, having a sufficiently fine mesh to hold back all but microscopic objects, and if it is passed through *clean* linen or fine muslin as well so much the better.

The lime should not be added as calcium oxide or quicklime (CaO), but as slaked lime or hydrate of lime (CaO, $H_2O$). The latter contains theoretically over 75 per cent. of oxide of calcium (CaO), but as it is practically impossible to get it absolutely pure, 60 per cent. (factor 1·67) would be a much safer figure to adopt.

It will be remembered that 4 grains of calcium oxide (CaO) were needed, so 4 × 1·67 × 10 = 66·8 grains (say, 1 drachm, 7 grains) are required.[1] It is best to weigh out this amount, mix it into a

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[1] With a small Apothecaries' balance (having a pan of $2\frac{1}{2}$ in. diam.) the maximum amount of substance (say, of calcium hydrate) that can be conveniently " massed" on the pan is about 100 grains. For larger amounts, a letter weight balance, or for still larger amounts a kitchen balance may be used. Figs. 7 and 8 represent a cheap dispenser's and a more delicate balance, respectively.

paste with a little rain-water in a small cup and transfer the mixture to the 10 gallons of rain-water, rinsing the cup out several times afterwards to ensure that all the lime has been washed out. Then stir
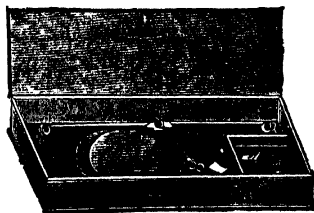


FIG. 7.
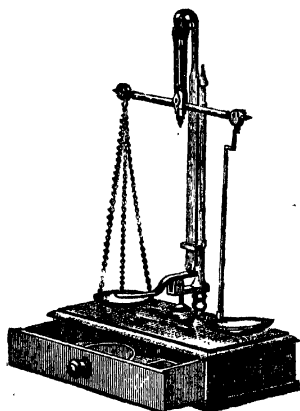


FIG. 8.

thoroughly for five to ten minutes and leave for eight to twelve hours to allow of sterilization taking place.

Of course, if preferred, the lime may be added as

" milk of lime." Weigh out 1½ oz. (Imperial) of
slaked lime on an ordinary letter weight balance,
and, if accuracy is aimed at, add to it 12 grains of
lime weighed on Apothecaries' scales. Transfer
the lime to a 12 oz. bottle, having a mark at
10 oz. capacity and containing, say, 5 oz. of water.
Shake vigorously for several minutes, then make
up with water to the 10 oz. mark. One oz. of
the shaken mixture, *measured quickly*, will be the
correct dose, approximately, for 10 gallons.

Another method is to use lime-water. The
solubility of CaO is nearer 1 in 900 than 1 in 1,000
but having regard to loss of strength on keeping,
the latter is the safer figure to adopt. Further,
for the sake of simplicity, the dose may be taken
at 70 instead of 66·8 grains per 10 gallons. Then
the proportions are 0·9 gallon (= 7 pints, 4 oz.)
of lime-water to 9 gallons of rain-water. The
lime-water may be prepared in bulk as follows :
'Fit a barrel, capable of holding rather more
than 30 gallons, with a stopcock, about 3 inches
from the bottom. Raise a foot or two from the
ground for " drawing-off " purposes. Pour 2 or
3 gallons of rain-water into the barrel and add
an *excess* (say, 1 lb.) of slaked lime ($CaO, H_2O$),
mixing the lime and water very thoroughly. Then
bring up to 30 gallons, stirring all the time and
place a tightly fitting lid on the mouth of the barrel.
The clear liquid drawn off from the tap will be
approximately of the strength of 1 in 1,000.

The next stage is neutralization of the excess lime. Rinse out a 100 c.c. measuring cylinder and small flask with the liquid. Then measure out 70 c.c. and transfer to flask and estimate the calcium oxide (CaO), using phenol phthalein and methyl orange in the way indicated previously (p. 16). Suppose the phenol phthalein and methyl orange· "readings" are 3·5 and 4 respectively; then 3·5 × 2 = 7 - 4 = 3 × 10 (for 10 gallons) = 30 is the number of grains of calcium oxide (CaO) which require neutralization. There is a considerable number of ways of effecting this object. (*See*, however, first paragraph, p. 31.)

(1) *Sodium hydrogen phosphate* (Na$_2$ HPO$_4$, 12 H$_2$O)[1] may be used, the practically insoluble calcium phosphate being precipitated as a flocculent white deposit and sodium hydrate being left in solution. (*See* Table XVII., p. 92.)

$$168 \qquad 716 \text{ (factor 4·26)}$$
$$3\,CaO + H_2O + 2\,Na_2HPO_4, 12\,H_2O = Ca_3\,(PO_4)_2 + 4\,NaHO + 12\,H_2O.$$
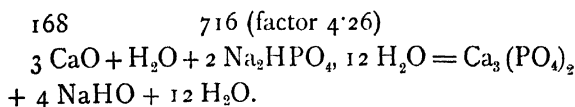
The amount required is obviously 30 × 4·26 = 127·8 grains (say, 2 drachms, 8 grains)[2] of sodium phosphate.

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[1] The writer has purposely chosen, as far as possible, preparations which are used medicinally and are to be found in the British Pharmacopœia.

[2] Weights may be purchased from 10,000 grains down to $\frac{1}{10}$ grain which avoid all the complications of scruples,

As it is perhaps undesirable to leave sodium hydrate (NaHO) in solution, sodium bicarbonate ($NaHCO_3$) may be added to change it into carbonate of soda ($Na_2CO_3$), which in its turn will act on the calcium sulphate ($CaSO_4$ permanent hardness).

.   160               336 (factor 2·0).
   $$4\,NaHO + 4\,NaHCO_3 = 4\,Na_2CO_3 + 4\,H_2O.$$
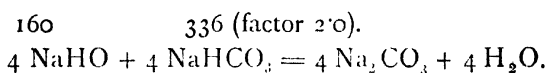
The amount required is $30 \times 2·0 = 60$ grains (1 drachm) of sodium bicarbonate ($NaHCO_3$), which theoretically would produce about 76 grains of sodium carbonate ($Na_2CO_3$) or enough to remove about 7 degrees of permanent hardness.

This is in excess of the permanent hardness of country rain-water, but sodium carbonate in small doses is quite innocuous.

   $$Na_2CO_3 + CaSO_4 = Na_2SO_4 + CaCO_3.$$
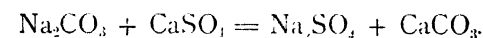
The sodium sulphate ($Na_2SO_4$) produced is soluble, innocuous and does not cause curdling of soap. The calcium carbonate ($CaCO_3$) is soluble only to the extent of about 1·4 grains per gallon.

127·8 grains (say, 2 drachms, 8 grains) of sodium phosphate are therefore added to the excess-limed rain-water and the mixture stirred for a few minutes,

drachms and ounces (Apothecaries' weights) and ounces and pounds (Imperial weights). Both as regards weights and measures it seems a great pity that we do not finally adopt the simple and scientific systems practised by Continental · nations.

and then 60 grains (1 drachm) of sodium bicarbonate added as well and the mixture again stirred.

After settlement, preferably for eight to twelve hours, the clear liquid is ready for domestic use.

(2) Alternatively, *Aluminium sulphate* crystals $(Al_2 (SO_4)_3, 18 H_2O)$ may be used to neutralize the excess lime. (*See* p. 78.)

168        666 (factor 3·96)

$$3 CaO + Al_2 (SO_4)_3, 18 H_2O = Al_2O_3 + 18 H_2O + 3 CaSO_4.$$
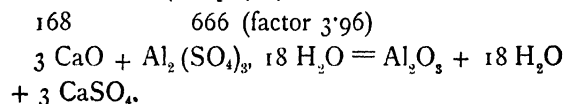
The amount required is thus $30 \times 3·96 = 118·8$ grains (nearly 2 drachms) of crystallized sulphate of alumina. As this would not remove the permanent hardness formed ($CaSO_4$ being soluble), it may be desirable to add subsequently carbonate of soda (crystals).

408        858 (factor 5·11).

$$3 CaSO_4 + 3 Na_2CO_3, 10 H_2O = 3 Na_2SO_4 + 3 CaCO_3 + 30 H_2O.$$
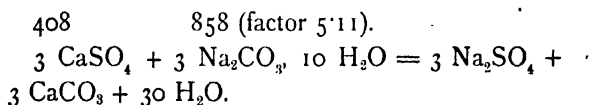
Hence $30 \times 5·11 = 153·3$ grains ($2\frac{1}{2}$ drachms, 3 grains) of sodium carbonate are required.

If it is required as well to remove the original permanent hardness of the rain-water, an additional 28·6 grains of sodium carbonate (crystals) for each degree of hardness is required per 10 gallons.

118·8 grains (say, 2 drachms) of aluminium sulphate are therefore added to the excess-limed rain-

water, the mixture stirred for a few minutes and then 153·3 grains (2½ drachms, 3 grains, or more if the original permanent hardness has to be removed) of sodium carbonate added as well and the mixture again stirred.

Unfortunately, sodium carbonate has a solvent action on aluminium hydrate, and instead of acting on the sulphates may have a tendency to interfere with the coagulating effect of the aluminium sulphate. In the case of lime-treated peaty waters, at all events, the writer has obtained better clarification by its omission.

.After settlement, preferably for eight to twelve hours, the clear liquid is ready for domestic use.

(3) Instead of the phosphate or aluminium sulphate methods, the excess CaO could be neutralized directly and simply with *sodium bicarbonate* (NaH CO$_3$), although the clarifying action is apt to be much less satisfactory (*see* p. 96).

168    504 (factor 3).    318 (factor ·63).

$$3 \, CaO + 6 \, NaHCO_3 = 3 \, Na_2CO_3 + 3 \, CaCO_3 + 3 \, H_2O.$$

30 × 3 = 90 grains (1½ drachms) of sodium bicarbonate (NaHCO$_3$) required which by producing 56·7 grains of Na$_2$CO$_3$ (90 × ·63 = 56·7) would remove about 5 to 6 degrees of permanent hardness.

$$Na_2CO_3 + CaSO_4 = Na_2SO_4 + CaCO_3.$$
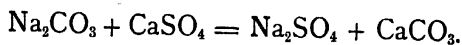
This is about the hardness of a town rain-water,

but country rain-water would be softer. Any slight excess of $Na_2CO_3$, however, is, as already suggested, harmless, possibly even beneficial.

Another plan would be to place the 90 grains of sodium bicarbonate ($NaHCO_3$) in a flask with a little water, fit the neck with a rubber bung and bent glass tube, one end of which is placed in the lime-treated water. With a spirit lamp heat the contents of the flask and boil briskly for a few minutes ; the carbonic acid gas ($CO_2$) will be driven off and combine with the CaO to form the relatively insoluble carbonate of lime.

$$6\ NaHCO_3 = 3\ Na_2CO_3 + 3\ H_2O + 3\ CO_2$$
$$3\ CO_2 + 3\ CaO = 3\ CaCO_3.$$
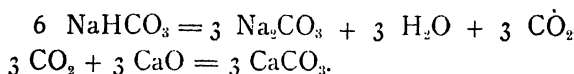
Speaking of the first named plan, 90 grains ($1\frac{1}{2}$ drachms) of $NaHCO_3$ are added to the excess-limed rain-water and the mixture stirred for several minutes. After settlement, preferably for eight to twelve hours, the clear liquid is ready for domestic use.

(4) Another very convenient way of neutralizing the excess CaO is to prepare *carbonic acid water* (*see* p. 99). For this purpose Gasogene or Sparklet Syphons may be used. Full instructions are issued with the apparatus and all that need be said here is that the water used should be above suspicion. Perhaps the simplest way is to bring 30 oz. of rain-water to the boil and add to it 10 oz. of non-.

boiled rain-water. When cool, the mixture will be free from the germs of water-borne epidemic disease, and suffice in volume for the 2-pint size of apparatus. After the water has been charged with carbonic acid. gas, a portion of the excess-limed rain-water (say, 2 oz.) is placed in a small bottle or flask and phenol phthalein added, when the liquid will turn bright pink. A little of the carbonic acid water is run into any convenient vessel and 10 c.c. of it drawn up into a graduated 10 c.c. pipette, and this is added very gradually to the liquid in the flask until the pink colour disappears. Half the amount used multiplied by 3oo[1] gives the volume, in cubic centimetres, required to neutralize 10 gallons of the excess limed rain-water.
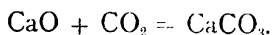
$$CaO + CO_2 = CaCO_3.$$

After settlement, preferably for eight to twelve hours, the clear liquid is ready for domestic use.

An excess of carbonic acid water should preferably not be added as then the relatively insoluble carbonate of lime ($CaCO_3$) is re-dissolved, forming bicarbonate of lime, thus hardening the water.

$$CaCO_3 + H_2O, CO_2 = CaCO_3, H_2CO_3.$$
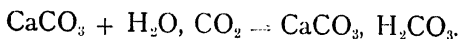
There would, of course, be no objection to adding an excess of carbonic acid water subsequently, that is, after the clear liquid has been separated from the deposited carbonate of lime.

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[1] Because 2 oz. $= \frac{1}{800}$ part of 10 gallons.

Indeed, such a procedure would give "bite" and flavour to the final product.

## SUMMARY AT THIS STAGE.

Ten gallons of rain-water require to be treated.

(*a*) Determine, in the way already described, the amount of CaO used up by the $CO_2$, &c., in the rain-water (p. 14).

(*b*) Determine the permanent hardness (*see* p. 18).

(*c*) Sterilize with 30 × 1·67 (+ grains of CaO found under (*a*) × 1·67) grains of calcium hydrate ($CaO, H_2O$). (*See* p. 19.)

(*d*) Estimate, in the manner previously set forth, the amount of CaO left over after sterilization per 10 gallons (p. 22).

(*e*) For sodium phosphate and sodium bicarbonate treatment, multiply figure obtained under (*d*) by 4·26 and 2·0 respectively (p. 22).

(*f*) For aluminium sulphate and sodium carbonate (*see*, however, remarks on p. 25) treatment, multiply figure obtained under (*d*) by 3·96 and 5·11 (+ 28·6 for every degree of permanent hardness) respectively (p. 24).

(*g*) For direct sodium bicarbonate method, multiply figure obtained under (*d*) by 3 (p. 25).

(*h*) For carbonic acid water method use a Gasogene or Sparklet apparatus and add a neutralizing quantity of the $CO_2$ charged water to the excess-limed rain-water (p. 26).

The purification processes here described offer to the student of chemistry no difficulties either in principle or practice. Nevertheless, there are many persons who will be discouraged by the technical terms used, and by the apparent complexity of the procedure. For these some *simpler* (although admittedly " blind ") methods may be described.

A fairly safe figure for the amount of oxide of lime (CaO) used up by the dissolved carbonic acid gas, &c., in *freshly* collected samples of rain-water would be one grain per gallon. Sixteen samples of freshly collected samples of town rain-water gave an average of o·8. Of course, in the case of rain-water stored for a long time in tanks containing much decomposing organic matter the water might be almost saturated with $CO_2$, and, if the tanks were made of concrete, bicarbonates would be formed which would also use up a certain proportion of the lime (CaO). In these cases actual tests ought certainly to be made.

A reasonably safe figure for bactericidal purposes would be about 3 grains per gallon of lime (CaO) with about twelve hours' contact. Very impure samples may possibly require a larger dose, or more prolonged contact. On the other hand, the dose suggested is in excess of ordinary requirements.

The reason for giving about twelve hours for sterilization and about twelve hours for subsequent neutralization, clarification, &c., is that the first part of the process may conveniently be started in the morning and the final part in the evening, the completely treated water being ready for drinking on the following morning. This involves, of course, the tanks or vessels for treatment being in duplicate. The important point is that *rapid* chemical sterilization processes labour, in the writer's experience, under the serious disadvantage of *super*-dosing, that is, of using far more of the chemical than is *actually* required owing to the duration of contact being unduly curtailed. This is apt to be specially true when the water to be sterilized is at a low temperature. Under abnormal conditions short contact may be absolutely unavoidable, but, generally speaking, the practice is to be condemned.

Slaked lime or hydrated lime ($CaO$, $H_2O$) contains nominally over 75 per cent. of oxide of lime ($CaO$), but 60 per cent. would be a safer figure to adopt (factor 1·67).

Hence $(1 + 3) \times 1\cdot67 = 6\cdot68$ grains (1 drachm, 7 grains) per gallon is the amount of slaked or hydrated lime ($CaO$, $H_2O$) required to sterilize rain-water within twelve hours.

Dealing in round numbers, 67 grains (1 drachm, 7 grains) of slaked lime are therefore added to 10 gallons of rain-water, the mixture stirred for five to fifteen minutes and then left for twelve hours to effect sterilization.

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Such a water could be drunk with *perfect safety without any further treatment*, the amount of excess lime being too small to give rise to any taste of lime, or to produce any injurious effects when ingested.

On the other hand, the process is incomplete and might be considered to call for neutralization of the excess lime, with, perhaps as well, clarification by coagulants.

Hence, the following additional processes are put forward tentatively.

For the sake of simplicity it is assumed that, after sterilization, the excess lime (CaO) is equal to 30 grains per 10 gallons.

Add to the sterilized 10 gallons of rain-water one or other of the following substances :—

| Sodium hydrogen phosphate, 128 grains (2 drachms, 8 grains). Then sodium bicarbonate, 60 grains (1 drachm). | Aluminium sulphate, 110 grains (about 2 drachms). Then (*see*, however, remarks on p. 25) sodium carbonate, 153 grains (2½ drachms, 3 grains). | Sodium bicarbonate, 90 grains (1½ drachms). | Neutralizing quantity of carbonic acid water. |

The first two processes aim not only at neutralization, but clarification and softening. The last two exercise a softening influence, but their clarifying effect is negligible.

In provisionally fixing the bactericidal dose of *excess* CaO at 3 grains per gallon, regard has been had to the duration of contact (eight to twelve hours), providing a wide margin of safety, and the

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variable quality of the rain-water. With a contact of one to seven days the dose may safely be reduced from three (assuming this to be sufficient with eight to twelve hours' contact) to from about two to mere traces. The matter requires furthur study, but the doses about to be suggested probably err on the side of safety, as the beneficial effect of storage would be (so to speak) superimposed on the germicidal action of the lime. Say, 2, 1, 0·5, 0·25, 0·125, 0·0625 and 0·03125 grains of CaO per gallon for one, two, three, four, five, six, and seven days' contact (*plus* 1 grain per gallon in each case for $CO_2$, &c., *see* p. 29).

Putting on one side questions of clarification, &c., the "rain-water purifier" might perhaps not unreasonably prefer to rely on time rather than on dose, and have tanks in *duplicate* for alternate use to hold either seven, six, five, four, three, two or one days' supply. (*See* Table XVI., p. 86.)

Working on a ten-gallon a day basis the dose and tankage accommodation would, if the foregoing assumptions are sound, be approximately as shown in Table VIII.

Of course, especially with the smaller doses here given, it is desirable first to determine accurately the amount of CaO used up by the dissolved $CO_2$, &c., in the rain-water, and then calculate the amount of hydrate of lime to be added so as to give an excess of CaO of 2, 1, 0·5, &c., &c.

Indeed, having regard to the innocuous, if not

beneficial, effect of minute doses of lime, a minimum dose of 0·25 excess CaO, with not less than four days' contact, would seem to be the wisest course to pursue.

TABLE VIII.—LIME, TIME AND TANK CAPACITY IN RELATION TO STERILIZATION.

*Ten Gallons a Day Basis, Tanks being in Duplicate and used Alternately. (Doses based partly on experimental data, and partly on empirical grounds.)*

| | | Hydrate of lime (CaO, H.O) (grains) | | | | | | Capacity of tanks (gallons) |
|---|---|---|---|---|---|---|---|---|
| 1 day's contact | | 50·1, say 50 (approximately 2 CaO in excess) | | | | | | 10 |
| 2 „ | „ | 33·4 | „ 33 | „ | 1 | „ | „ | 20 |
| 3 „ | „ | 25·05 | „ 25 | „ | 0·5 | „ | „ | 30 |
| 4 „ | „ | 20·875 | ·, 21 | „ | 0·25 | „ | „ | 40 |
| 5 „ | „ | 18·788 | „ 19 | „ | 0·125 | „ | „ | 50 |
| 6 „ | „ | 17·744 | „ 18 | „ | 0·0625 | „ | „ | 60 |
| 7 „ | „ | 17·222 | „ 17 | „ | 0·03125 | „ | „ | 70 |

For health or taste purposes, and putting on one side questions of clarification or hardness, water treated in this manner could be *safely drunk without any further treatment.*

Some reference should perhaps also be made to the use of acids for neutralization purposes. The writer sees no objection to the use of either mineral or organic acids in this connection, provided the treatment rests in safe hands. Of the mineral acids, phosphoric acid (the dilute phosphoric acid of the Pharmacopœia, *acidum phosphoricum dilutum* may be used), has the advantage of producing the practically insoluble calcium phosphate, and so reducing the hardness of the " lime-treated " water.

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On the other hand, the organic citric or tartaric acids are crystalline, and so can be added by weight. They are medicinal preparations and practically non-poisonous. In combination with lime, the salts produced have an anti-scorbutic tendency, and, in the amounts involved, are perfectly innocuous. Each grain per gallon of excess CaO requires 1·24 and 2·66 grains of citric and tartaric acids respectively.

In conclusion, the chief points to be noted are as follows :—

Rain-water can be sterilized successfully with an innocuous dose of lime, say, 6·7 grains of *slaked* lime per gallon of water. (*See also* Tables XI., XIV., XVI. and XVII.)

If questions of neutralization of the excess lime and of clarification and softening are considered necessary or desirable, these results can be achieved by comparatively simple means.

Granting the approximate accuracy of certain assumptions, the processes involved require no chemical knowledge, and become a matter of mere simple weighing of the necessary ingredients.

The non-expert reader may find it desirable to pay most attention to pp. 29 to 34.

Consideration may next be given to the sterilization of rain-water by means of heat and by the use of chlorine compounds.

# CHAPTER III.

## RAIN-WATER *(Continued)*.

Sterilization by means of heat—three parts boiled, one part not boiled method—Clarifying methods—Sterilization by means of chlorine—Bleaching powder—" Chloros "—Electrolytic compounds—Prejudice against " doping " waters—Doses of chlorine—How administered—Use of sodium sulphite—Combination with clarification methods —Combined lime and chlorine methods—How best applied—Neutralization of the proportion treated with lime—Less chance of taste—Liquid chlorine—Electrolytic compounds—Ozone—Ultra-violet rays—Household devices—" Halazone "—Concluding remarks (p. 46).

### STERILIZATION BY MEANS OF HEAT.

This method does not aim directly at clarifying a water, or eliminating taste, or purifying it chemically.

Nevertheless, from the point of epidemic water-borne disease, it has no equal, and it differs from all other kinds of treatment, inasmuch as it is applicable to every kind of water (rain-water, river-water, surface-water, spring-water, well-water, &c.).

The old rule was to boil a water violently for at least five minutes; this procedure was based partly on empiricism, and partly on a knowledge of the limitations of human nature.

It has the disadvantage of robbing a water of

most of its dissolved gases, and therefore rendering it less palatable.

A perfectly safe rule to adopt is to bring three parts of water barely to boiling point ($212°$ F. ; $100°$ C.), and add one part of " unboiled " water. The mixture within five minutes will be innocuous, whatever the temperature of the water was antecedently, and the dissolved gases will only be partly dissipated. For example, even with water initially at the freezing point, the temperature of the mixture would be $167°$ F. ($75°$ C.), a temperature more than sufficient to kill the typhoid bacillus within five minutes (*see* Miscellaneous Experiments, p. 98).

Of course, if it is desired as well to reduce the colour and precipitate the bulk of the suspended matter, heat may be used for sterilization purposes, and aluminium sulphate as a coagulant. About 3 to 6 grains of aluminium sulphate and .3·9 to 7·8 grains of sodium carbonate crystals may be used for this purpose per gallon of rain-water.

Perhaps a few words should be added as regards distillation processes. Practically any water may be used for distillation purposes, and distilled water is absolutely safe from a bacteriological point of view. Most people dislike the taste of distilled water, but the writer disagrees with those who consider it actually injurious to health. Dr. W. P. Mason[1] quotes Surgeon-General W. C. Braisted, of the U.S. Navy, as saying :—

[1] " Water Supply," by Dr. W. P. Mason (John Wiley and Sons).

" The use of distilled water on ships of the Navy has always tended to the very best of health conditions. In my opinion the use of distilled water offers the ideal drinking fluid for human consumption."

Of course, unless the water is brackish, or contains an injurious proportion of salts, or for some other reason cannot be drunk directly, there is no occasion to distil it, heating in the way already described being all that is required. As distillation is only required in quite exceptional circumstances, and as the provision of a *still* and condensing and heating apparatus is a mere matter of purchase, involving no special knowledge, the matter need not be considered further. Any responsible firm dealing in laboratory apparatus can supply full information on the subject.[1]

### STERILIZATION BY MEANS OF CHLORINE.[2]

· There are at least four ways of utilizing this method :—

(1) Bleach solution. Bleaching powder or chloride of lime should contain about 33 per cent. of available chlorine.

· (2) Chloros (solution of sodium hypochlorite) contains 10 to 15 per cent. of available chlorine.

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[1] For large plants to deal with sea-water, p. 1820 of " Kelly's London Directory " (1917), may be consulted.

[2] Brómine and Iodine have also been employed for sterilization purposes, but their use cannot be considered here.

37

(3) Liquefied chlorine gas (100 per cent. value).

(4) Electrolytic compounds. These are prepared electrolytically from various chlorides (e.g., sea-water), and the percentage of available chlorine depends on the concentration of salt and other factors.

It seems a great pity that so much prejudice surrounds the use of chlorine for sterilization purposes.[1] As a pioneer (Lincoln Water Supply, 1905) on this subject, the writer has had to contend with a great deal of well-meant criticism. After all, it is only natural to look with suspicion on what many persons regard as a "doped" water. It is foolish to try and ride roughshod over the opinions of others merely because they do not coincide with our own. Yet if this War has taught us anything, it is the triumph of expediency over sentimentality. When all has been said, the *safety* of a water supply comes *first*, and if this end can only be achieved by chemical treatment, all other considerations should occupy a secondary position.

Rain-water varies so much in chemical composition that it is difficult to suggest a dose of chlorine suitable for all, or, perhaps, even a majority of, cases. For example, unless suitably protected from outside sources of contamination, rain-water may contain much decomposing vegetable matter, many insects, and even the bodies of mice, rats, and birds.

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[1] See Chapter V., "Studies in Water Supply," and Chapter IV., "Rivers as Sources of Water Supply."

Strictly speaking, the strength of the bleaching powder and chloros in terms of available chlorine should always be determined. But as this involves skilled chemical knowledge, experience and technique, it has been assumed in what follows that bleaching powder contains 33 per cent. (factor 3), and chloros 12 per cent. (factor 8·3) of available chlorine.

On the whole, it would seem wisest to employ a somewhat larger dose than is actually required, and to counteract the effect of this by prolonged contact, and, if necessary, the final use of an " anti-chlor."

A dose of 0·5 part of available chlorine per million parts of water (1 in 2 millions) with twenty-four hours' contact, and then the addition (if found desirable) of a de-chlorinating dose of sodium sulphite is recommended. This corresponds with 1·05 grains of bleaching powder or 0·00664 oz. of chloros per 10 gallons of water.

As these are inconveniently small amounts to deal with (by liquid or measure) it is desirable to work with standard solutions, as follows :—

Weigh out 10·5 grains (breaking up any lumps) of bleaching powder and transfer to a small bottle containing 2 oz. of rain-water and some lead shot. Shake thoroughly for several minutes, allow to settle and pour the more or less clear liquid into a 10- oz. measuring glass. Add another 2 oz. of rain-water to the small bottle, shake vigorously.

allow to settle and pour the clear liquid into the measuring glass. Repeat this procedure twice more so as to ensure that practically all of the active part of the bleaching powder has been extracted, and then finally make up the measuring glass to 10 oz. with rain-water ; stir, allow to settle, and transfer the clearer portion to a stoppered bottle. · The dose is now obviously 1 oz. for every 10 gallons of rain-water.

Alternatively, the 10·5 grains may be put in a mortar and mixed repeatedly with rain-water, the clearer portion being transferred each time to a 10 oz. measuring cylinder, Finally, rain-water.is added up to the 10 oz. mark, the mixture stirred, then allowed to settle, and the clear portion poured into a stoppered bottle.

As regards the chloros, if this is diluted with 19 volumes of rain-water ( = 1 in 20), then 1·0624 (say 1) drachm of the mixture per 10 gallons gives a dose in available chlorine of 0·5 per million.

Ten gallons of rain-water are placed in a suitable vessel and either 1 oz. of bleach solution or 1 drachm of diluted chloros added, and the mixture stirred for a few minutes.

After twenty-four hours, measure out 8 oz. of the now-sterilized rain-water into a convenient bottle or flask. Take the temperature of the liquid, if it is below 10° C. add a little freshly prepared potassium iodide and starch solution (see p. 116). If above 10° C., the liquid should, before testing, be.

cooled, if practicable, with a mixture of ice and salt to· below 10° C., as otherwise the delicacy of the test is much impaired.

If there is no blue reaction, or only the very faintest tint, no sodium sulphite need be added and the liquid may be drunk with impunity. On the other hand, if there is a decided blue reaction, sodium sulphite solution (0·1 per cent.) should be run in from a burette and the number of cubic centimetres needed to remove the blue colour "read off." Obviously, this amount × 200 will give the dose of sodium sulphite required. Those who are averse to making actual tests might proceed on the basis that each part of available chlorine requires about 3·5 parts of sodium sulphite. With the dose here suggested (0·5 per million) 1·225 grains of sodium sulphite would be required. As, however, all, or nearly all, the available chlorine is likely to have been used up at the end of twenty-four hours, it is probable that about ½ grain of sodium sulphite would be sufficient. It is perhaps unnecessary to warn the reader that on no account must the sodium sulphite be added until the chlorine has exercised its sterilizing action. This, of course, would have the effect of destroying the bactericidal effect of the chlorine.

The chlorine treatment may be combined with clarification, but if aluminium sulphate is úsed, care must be exercised not to add more than will be .neutralized by the alkalinity of the rain-water.

For example, after the addition of the bleach or chloros solution add from 30 to 60 grains (per 10 gallons) of aluminium sulphate according to the quality of the rain-water, and then, to avoid any risk of acidity, from 39 to 78 grains of sodium carbonate crystals.

$$666 \qquad\qquad 858 \text{ (factor about } 1\cdot3)$$
$$Al_2 (SO_4)_3, \ 18 \ H_2O + 3 \ Na_2 \ CO_3, \ 10 \ H_2O =$$
$$Al_2 O_3 + 3 \ Na_2 SO_4 + 3 \ CO_2 + 28 \ H_2O.$$
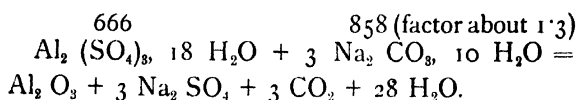
If this method is adopted, it is best to do without the sodium sulphite, as its addition at the end of the twenty-four hours necessarily means disturbing the precipitate produced by the aluminium sulphate.

Of course, if it is added as a solution, it might be possible to stir so gently and superficially as to secure fair mixing without appreciable disturbance of the precipitate.

Alternatively and preferably, the clear liquid might be " run " into another vessel and the sodium sulphite added to it. Speaking generally, the non-expert use of sodium sulphite is almost contra-indicated, unless in infinitesimal doses, or in those cases where the excess of chlorine is so marked as to impart a chlorinous taste to the treated water. In passing, the writer is prone to admit that it is not always easy for the non-expert worker to steer between the Scylla of an impure water, and the Charybdis of an imperfectly treated supply. Nevertheless, " microbial " safety stands first, and even.

gross blunders with the chemicals here recom-
mended could hardly render a water actually
injurious to health.

Yet another alternative plan may be suggested.
The· dose of chlorine may be doubled, the duration
of contact halved, and then wood charcoal (say 20 to
200 grains per gallon, according to the impurity of
the water) added together with aluminium sulphate
and a neutralizing quantity of sodium carbonate.
The charcoal interferes, but not seriously, with
precipitation and it has the effect of removing the
chlorinous and the sooty taste.

### Combined Lime and Chlorine Methods.

It is obvious that these two processes may be
combined in a variety of ways.

For example, 5 gallons of rain-water may be
placed in each of two vessels ($A$) and ($B$).

($A$) receives 33 grains ($\frac{1}{2}$ drachm, 3 grains) of
hydrate of lime.

($B$) receives $\frac{3}{4}$ oz. of bleach solution (10·5 grains
of bleaching powder in 10 oz. of water).   This
equals a dose of 0·75 in 1 million (instead of
0·5 per million) as the duration of contact is only
twelve hours.

·After ᶜ twelve   hours   ($B$)   receives   an   anti-
· chlorinating dose of sodium sulphite, say 0·4594

grain, allowing for about half the chlorine having been used up.

The contents of (*A*) and (*B*) are then poured into a third vessel (*C*) capable of holding 10 gallons, and 45 grains (2 scruples, 5 grains) of sodium bicarbonate added to neutralize the lime and remove (as carbonate) the permanent hardness, and the mixture left to settle for twelve hours.

Alternatively (*C*) may be treated as follows :—

(*a*) With 64 grains (1 drachm, 4 grains) of sodium phosphate and 15 grains (½ scruple, 5 grains) of sodium bicarbonate, or,

(*b*) With 60 grains (1 drachm) of aluminium sulphate and 77 grains (1 drachm, ½ scruple, 7 grains) of sodium carbonate, or,

(*c*) With a neutralizing quantity of "carbonic acid water."

There is less chance of a chlorinous taste with this combined method, although it loses a little in point of simplicity.

As regards the use of *liquid chlorine*, special apparatus has to be provided, and although the writer has had, on the whole, a favourable experience of its use on a large scale, he is inclined to think that for very small volumes of water some of the other processes here described are for the present to be recommended. It is quite possible, .

however, that some ingenious inventor will design a form of apparatus which will sterilize even small volumes of water simply, cheaply and effectively.

Little need be said about *electrolytic* compounds. Where electric current is available, it may be used either in connection with an ozonizing apparatus to produce *ozone* (a most powerful bactericidal agent), or with an electrolyzer to form *hypochlorites* from salt solution, or else with a quartz-mercury lamp to yield *ultra-violet* rays. The forms of apparatus on the market, however, for fulfilling these objects are usually designed for dealing with larger volumes of water than are being considered in this treatise. Waters containing much suspended matter should be filtered before being exposed to sterilization by means of ultra-violet rays. The writer, however, is rather trying to avoid purification processes which require filtration.

The fact that there has been no wide-spread adoption of any household device for sterilization purposes seems to point to inventors having failed to convince the public, or their advisers of the cheapness and "fool-proof" efficiency of the apparatus on the market.

As regards dose, enough has already been said to indicate the probable amount of active substance required for sterilization purposes.

Before closing this section, reference should

perhaps be made to a new chlorine compound, p-sulphondichloraminobenzoic acid (called *halazone*) recommended by Dakin and Dunham (*British Medical Journal*, May 26, 1917) for sterilizing small quantities of water. Halazone can be made up in tablets, and to sterilize a quart of water one or two tablets, according to its quality, are said to be required. Apparently sterilization takes place within thirty minutes (*see* also Halazone for Water Sterilization, *British Medical Journal*, August 11, 1917).

In conclusion, the chief points to be noted are as follows :—

Rain-water can be sterilized by means of heat (3 pints boiling, 1 pint unboiled) and clarified with coagulants (e.g., aluminium sulphate). (*See* also p. 98.)

Various chlorine preparations (e.g., bleaching powder) may be used successfully for sterilization purposes (say, 0·105 grain *per* gallon), and any excess of active chlorine removed by means of an "anti-chlor." (e.g., sodium sulphite). Aluminium sulphate may be employed as well for clarification purposes. (*See* also Chapters VI. and VII.)

The lime and chlorine methods may be combined with some advantages.

Household devices for sterilizing waters by means of ultra-violet rays, ozone, &c., have not achieved wide popular success.

A substance termed " Halazone " has recently been introduced in tablet form for household sterilization purposes.

The diligent and intelligent reader will, no doubt, by this time have come to the conclusion that, although the purification of rain-water may be a complex process, putting on one side complicating questions (e.g., turbidity, taste, &c.), *safety* may be secured always by adding 3 parts of boiling to 1 part of unboiled water, and usually by adding either 67 grains of *slaked* lime, or 1·05 grains of bleaching powder to 10 gallons of rain-water.

In the remaining chapters, other sources of water supply will be briefly dealt with, but, to save repetition, it will be assumed that the sterilization and purification processes (*see also* Actual Experiments, Chapters VI. and VII.) described under rain-water have been carefully studied. The necessity for sterilization has, so far, been assumed, but, of course, there are waters which are pure, bacteriologically, but unsatisfactory as regards colour, suspended matter, &c. In these cases, the addition of from 3 to 6 grains per gallon of aluminium sulphate is usually found to be most satisfactory, but in the case of soft water an alkali should be added as well—say 3·9 to 7·8 grains of sodium carbonate per gallon. The precipitate must be given time to settle and the clear liquid decanted for domestic use.

# CHAPTER IV.

## WELL-WATER AND SPRING-WATER.

## WELL-WATER.

Shallow[1] wells are so often contaminated in the
neighbourhood of dwellings, that their probable
impurity should be taken almost for granted.

Such waters, despite their unsafe character, are
frequently bright, clear and sparkling, and pleasant
to taste.

Their topographical relation to drains and cess-

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[1] Deep wells, especially if sunk through impervious strata,
are usually perfectly safe sources of water supply. Owing to
the excessi re and speculative cost of sinking they are seldom
found in connection with private individual supplies. In any
case the purity of the water is usually beyond question.

pools is most important. Hardly less vital is the kind of soil in which they are sunk (a good filtering medium or otherwise), the nature of their lining (pervious or impervious), and the possibility or probability of surface impurities reaching the supply. For example, a leaking or overflowing cesspool, situated at a higher level than, and not far distant from, a well, the intervening soil being highly porous or fissured, and the well itself shallow and unprotected either laterally from the surface downwards or vertically from below upwards from the rapid ingress of unpurified water, is an extreme illustration of obvious dangers not unfortunately always avoided. Medical officers of health in particular, but medical men generally, are specially trained in these matters, and if any doubt exists, their advice should be sought and taken, especially as it usually errs on the side of " safety."

The principles of purification remain much the same whatever class of water is dealt with, but the details require modification.

As a rule, well-waters are hard and not infrequently much of the hardness is what is known as " temporary," that is, it can be removed by boiling.

It is assumed in what follows that the preceding chapters have been carefully studied.

## Excess Lime.

Here, consideration must be given not only to dissolved carbonic acid gas ($CO_2$) but to bicarbon-

ates, which may be present in considerable amount ; otherwise all the lime added may be neutralized and rendered non-bactericidal.

The first step is the determination of the total hardness of the water.

Pour 70 c.c. of the water into a small bottle and from a burette " run " in a few drops of standard soap solution ($1$ c.c. $= 1$ grain per gallon $CaCO_3$) at intervals, shaking vigorously after each addition until a lather which remains unbroken for a few minutes is obtained. The number of c.c. used gives the total hardness of the sample. The permanent hardness is estimated in the way explained on p. 18. The difference between the two is the " temporary " hardness and is commonly due to calcium bicarbonate. The action of lime (CaO) on calcium bicarbonate is as follows :—

$$100 \qquad\qquad 56 \text{ (factor ·56)}$$
$$CaCO_3, H_2CO_3 + CaO = 2\ CaCO_3 + H_2O.$$
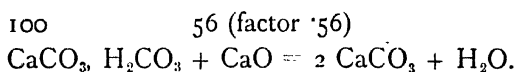
Suppose the temporary hardness was found to be 12, then $12 \times 0.56 = 6.72$ grains per gallon of CaO would be required. Add, say, $1.0$ for dissolved carbonic acid and, say, $3.0$ for bactericidal purposes ($=10.72$).

It will be remembered that this must be multiplied by $1.67$ if hydrate of lime is used ($10.72 \times 1.67 = 17.9$).

In order to obtain a more reliable figure, it is desirable to add this amount to a gallon (or, say,

one-tenth of it to one-tenth of a gallon) and then estimate the excess CaO with phenol phthalein and methyl orange in the way described on pp. 14 to 16.

Suppose the phenol phthalein reading is 5 and the methyl orange reading 7, then $5 \times 2 = 10 - 7 = 3$ grains per gallon of excess CaO, or the correct dose.

If found to be less or greater than 3, an obvious calculation will determine the correct amount to add.

Another way of estimating the dose of CaO required for sterilization purposes is to estimate the alkalinity. Seventy c.c. of the water are placed in a small flask, methyl orange added and then standard acid (1 c.c. = 0·001 gramme CaO) run in slowly from a burette until the yellow tint is beginning to change to pink (*see* p. 116). The number of cubic centimetres of standard acid solution used gives the number of grains per gallon of CaO likely to be needed to combine with the bicarbonates in the sample of water. To this must be added say 1 grain for dissolved $CO_2$ and 3 grains for bactericidal purposes.

Of course, the matter may be much more complex than is here indicated. For example, lime acts on magnesium salts as well as on bicarbonate of lime, and magnesium salts are not uncommon constituents of water.

Only a complete analysis by a highly skilled analyst could be expected to yield the fullest information, but determination of the alkalinity or the

temporary hardness, is an approximate guide to the amount required. Then one or more trial experiments with calculated amounts of lime, with subsequent estimation of the excess of lime actually left in the water, leaves no doubt as to the actual amount of lime required.

Unfortunately, most well-waters vary in composition from time to time, and this circumstance can only be met by checking the results periodically, or adding such an excess of lime as will cover all variations, so far as sterilization is concerned.

With waters having a very high temporary hardness, the excess lime should be considerable, as a relatively slight increase in the hardness might use up all the caustic alkalinity and destroy the bactericidal action.

Those who do not feel wholly competent to carry out these tests are advised to send a sample of the water in question to a skilled analyst and ask him to determine what amount of lime it is necessary to add to it, so as to leave 3 grains of lime (as CaO) per gallon in it in *excess*.

The fact is that with rain-water and very soft moorland waters the excess lime method may be used almost " blindly," because nearly all the lime is available for bactericidal purposes. With hard waters the case is widely different, most of the lime being exhausted in precipitating carbonates from bicarbonates.

For the sake of description, let it be assumed

that 18 grains ($\frac{1}{2}$ scruple, 8 grains) of hydrate of lime per gallon have to be added so as to leave an excess of 3 grains of CaO.

Working as before with a 10 gallon unit, 180 grains (3 drachms) of hydrate of lime are added to the water, the mixture well stirred and left to sterilize for eight to twelve hours.

As regards subsequent treatment, it should be remembered that well-waters do not usually require clarification, and so the sodium phosphate and aluminium sulphate methods are hardly needed.

Neutralization of the excess lime should be effected by means of sodium bicarbonate, the amount required being 30 × 3 = 90 ($1\frac{1}{2}$ drachms). This would produce 56·7 grains of sodium carbonate or enough to remove five to six degrees of permanent hardness. This is not at all an unlikely amount for a well-water, but even if it were less, the presence of a small excess of sodium carbonate would be of no importance.

Alternatively, "carbonic acid water" might be used to neutralize the excess of CaO in the way already explained under rain-water.

In either case, after addition of the sodium bicarbonate or the "carbonic acid water," the water should be left, preferably for eight to twelve hours, so as to allow the precipitate produced to settle to the bottom of the vessel.

As explained under rain-water, citric or tartaric acid might be employed for neutralization purposes,

the amounts required being 37·2 (⅓ drachm, 7 grains), and 79·8 grains (1 drachm, 1 scruple) respectively.

The sodium bicarbonate method, however, seems most suitable as producing a beautifully soft water.

As described under rain-water, the bactericidal dose of lime (CaO) is largely governed by the time it is allowed to act. Hence, by using tanks capable of holding one to seven days' supply (in duplicate) the dose could be so reduced that no neutralization of the excess of lime (CaO) would be really required, or, if needed, the amount of sodium bicarbonate necessary would be reduced proportionately.

On the other hand, as rain-water is usually very soft and well-water often very hard, the utmost care would have to be taken in the latter case to avoid any risk of *all* the lime being used up by the bicarbonates, &c., in the water. This, of course, would have the effect of robbing the lime of its bactericidal power.

As regards *heat, chlorine* and *electrolytic compounds, ozone* and *ultra-violet rays*, the remarks made under rain-water apply broadly to other sources of supply.

The *combined lime and chlorine* method is well suited for well-waters, having a high temporary hardness as perhaps as much as one-half or more may be sterilized by means of lime, the subsequent mixture of the limed and chlorinated waters pro-

ducing a sterile soft and tasteless water. Theo-
retically, whatever the number of grains per gallon
of temporary hardness was found to be, roughly
one-half (56 to 100), that amount of CaO would be
required for neutralization purposes. For example,
if the excess lime were equal to 3 grains per gallon,
·6 grains of temporary hardness would be removed
by it. Hence, if the temporary hardness were 12,
one gallon of the limed water would be neutralized
by 0·5 gallon of the chlorinated water (i.e., say 66
to 33 per cent.).

Obviously, the temporary hardness in grains per
gallon, divided by twice the number of grains per
gallon, of excess CaO gives the divisor for ascer-
taining the proportion of 1 gallon which 1 gallon of
limed water will neutralize.

In practice, it is best to mix the water in the
amounts as calculated, and then determine the alka-
linity with phenol phthalein and methyl orange as
previously described (p. 14). Where pp = the phenol
phthalein reading and mo = the methyl orange
reading, the following results may be obtained :—

TABLE IX.—ESTIMATION OF BICARBONATES, CARBONATES AND
HYDRATES (BASED ON A.P.H.A. TABLE).

(< = less than ; > = greater than).

| | Bicarbonates | Carbonate | Hydrates |
|---|---|---|---|
| (a) pp = 0 ... | mo | 0 | 0 |
| (b) 2 pp < mo ... | mo − 2 pp | 2 pp | 0 |
| (c) 2 pp = mo ... | 0 | 2 pp | 0 |
| (d) 2 pp > mo ... | 0 | 2 (mo − pp) | 2 pp − mo |
| (e) pp = mo ... | 0 | 0 | mo |

A (*d*) or (*e*) result implies that more chlorinated water is needed. A (*c*) result points to perfect neutralization. An (*a*) or (*b*) result indicates that the chlorinated water is in excess. Practically, under the conditions of experiment, results (*z*) and (*e*) could not possibly be obtained, as the former would mean that no lime had been added and the latter that carbonate of lime is absolutely (not merely relatively) insoluble.

## Springs.

Spring-water is often very pure, as the source of supply may be far distant and the passage of the water through the soil tends to rob it of any impurities. This, however, is not always the case, and if any doubt exists on so important a matter, a sample, or samples, should be sent to a competent expert, accompanied with any topographical or other notes which may assist in the interpretation of the results obtained.

If impure, its treatment may be carried out on lines broadly parallel with those suggested under well-waters. Putting on one side the so-called "ochre" and medicinal springs and other excep-. tional cases, the water from springs is usually bright, clear, sparkling, and most pleasant to drink.

In conclusion, the chief points to be noted are as follows :—

The principles of purification remain the same for all kinds of water, but in the treatment of well-water it should be remembered that the question of sterilization is frequently the most important factor to decide upon, clarification and removal of taste being seldom required.

Well-waters are often so hard that a sterilizing process, which involves softening as well, has many advantages (*see* Table XIX., p. 98). On the other hand, many persons may consider chlorine sterilization simpler (for dose, *see* p. 122).

Spring-water is often as pure as shallow well-water is impure, but when polluted, the treatment in the two cases may, as a rule, be carried out on broadly parallel lines.

The topographical surroundings of wells and springs are always of great importance.

The next chapter deals with the sterilization and purification of river, brook and lake-water for domestic use, and with *questions of taste.*

# CHAPTER V.

## RIVERS, BROOKS, AND LAKE-WATER.·

### (The Taste of Waters.)

Rivers, brooks, and lakes—Usually agreeable to taste—Very
variable as regards colour, physical appearances, chemical
composition, and bacteriological qualities—Pollutions
known and unknown (accidental)—Comparison between
waters impure but purified, and initially pure but liable
to chance contaminations—Soft waters and metallic
poisoning—Topographical survey essential—Suggestions
for treating different kinds of impure water—A few words
of advice—The taste of water—Concluding remarks
(p. 67).

Rivers, Brooks, and Lake-water (natural or
artificial).

These supplies present the widest variations
in quality, both chemically and bacteriologically.
They usually have an agreeable taste, in the
absence of excessive algal growths, although the
taste of very soft peaty waters, in the case of per-
sons used to a very hard water, is at first considered
mawkish. When the conditions are reversed, the
hard water, to begin with, seems to grip the mucous
membrane of the mouth and to have almost a
metallic taste. These sources of water supply may
be so pure as to be absolutely safe for drinking pur-
poses (excepting accidents) without any purification.

whatsoever. On the other hand, they may be grossly polluted with excremental matters and so be extremely dangerous sources of supply. The comparatively recent (1905) typhoid epidemic at Lincoln should be a warning of the potential danger attached to surface water supplies. Here, with a population of about 50,000 there were over 1,000 cases of typhoid fever and over 100 deaths. Surface waters vary greatly in chemical composition and physical qualities, and some are as hard as others are soft.

The mere fact that they are *surface* sources (in greater or less measure) of supply suggests caution, as, even if normally pure, they are always exposed to chance contaminations.

The purest burn in the lonely Highlands of Scotland may be fouled by a chance and reckless wayfarer. Should such a vagrant be a typhoid "carrier," the burn water will, for the time being, be infinitely more dangerous than an initially impure supply which has been subjected to adequate purification processes. Indeed, it might be argued, with some show of reason, that uniformly well purified waters of doubtful or even dangerous antecedents, may be safer than non-purified supplies of happier origin, if the latter are ever exposed to accidental pollutions of specific sort. As an example of the former, an adequately stored and efficiently filtered initially impure river-water might be taken, and, for the latter, a pure Highland burn in the track of

shooters and beaters, some of which might be irresponsible and conceivably at the same time diseased.

When peaty water is piped to a house, it should be remembered that these waters are often acid and act energetically on lead, and that lead is a cumulative and dangerous poison. In such cases, the water should be rendered alkaline by means of lime or soda before passing through lead pipes, or the pipes used (owing to their composition, or their internal coating) should preclude the possibility of metallic poisoning.

It is most important that these surface sources of supply should be carefully surveyed to see whether there is any possibility or probability of excremental pollution between their areas of origin and points of abstraction for domestic use.

The mere fact, let us say, of your having found it convenient to fix your residence near a stream should suggest the probability of others having been similarly influenced. If the habitations are situated higher up on the water-shed the danger is yours, if lower down, it is your bounden duty to see that the danger is not theirs.

Impure soft, peaty and discoloured waters may well be treated with lime, aluminium sulphate and sodium carbonate, in the way described under rain-water, and the treatment, if properly carried out, sterilizes and clarifies the water and leaves it very soft.
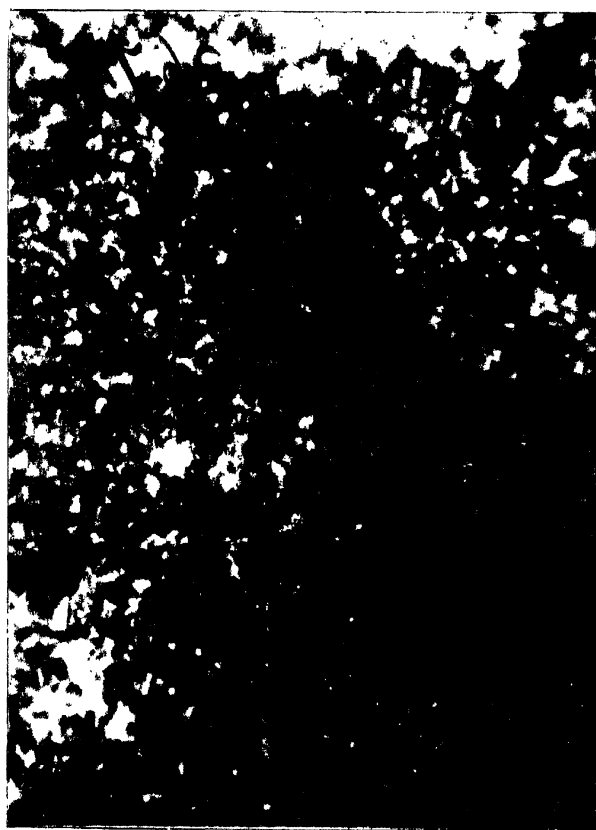
FIG. 9 — Suspended matter × 0.5 cm² in a river water during a flood
× 50 diameters

For contaminated hard waters which are not highly coloured, lime and bicarbonate of soda treatment yields satisfactory results.

Instead of lime, chlorine may be used as the sterilizing agent, and here it should be remembered that peaty discoloured waters contain much oxidizable matters, which may use up a considerable proportion of the chlorine.

River-waters are usually very turbid in flood-time and the use of lime, aluminium sulphate and sodium carbonate is attended with excellent results. Fig. 9 (for description *see* p. xv.) shows the suspended matter in 0·5 c.c. of a sample of river-water during a flood.

The lime and chlorine methods may also be combined in a variety of ways according to the particular requirements of the case.

Careful consideration of the suggestions made under rain-water and well-water will enable the reader to decide which is the best course to adopt.

Important points to be considered are :—

(*a*) What is the source of the supply; is it uniformly contaminated, or are chance accidental pollutions the only danger to health ? In this connection, remember that although the excreta of the lower animals is a most undesirable form of contamination, the greatest danger lies in the discharges of human beings, particularly those who

have the misfortune to be typhoid "carriers" (3 per one thousand according to some authorities).

(*b*) What is the character of the supply? Hard or soft, clear or discoloured, free from suspended matters or otherwise, rich in organic matter 'or the reverse, &c.

(*c*) If the verdict is unfavourable, questions of economy, sentiment and trouble must be ruthlessly set aside and the safety of the supply secured by sterilization at all costs. Absence of taste, freedom from colour and suspended matter, softness and reduction in the amount of oxidizable matter are less important than the destruction of all the germs of disease.

(*d*) If in doubt, sterilize the water or secure an alternative supply, or consult a competent expert.[1] If the suggested methods of sterilization and purification appear too complex, seek the advice of some person of experience in these matters. Never adopt a *laissez faire* attitude in the matter of water supply.

Before closing this chapter some reference may be made to questions of taste, as this is a subject

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[1] Readers who are ambitiously inclined, and desire to test for themselves the bacteriological qualities of water supplies are referred to pp. 138 to 188 of the author's little book, "Studies in Water Supply" (Messrs. Macmillan and Co., St. Martin's Street, London).

which is too often neglected; yet to many persons it is so important that they prefer to drink a pleasant flavoured water although it is known to be exposed to pollution, rather than a bacteriologically "safe" water which has an unpleasant taste or smell.

*The Taste of Water.*—This is a fascinating but difficult study, and the number of persons with a discriminating and reliable taste is comparatively few.

*Rain-water* has a peculiar, mawkish, unpleasant, sooty taste, and in the neighbourhood of towns may be almost undrinkable. One can recall the taste vividly to the remembrance of most persons, however old, by reminding them of the days of their childhood when, if they really were children, they sucked icicles broken off from roofs, gutters, waterspouts, &c. It is a faint but unforgettable taste and one most difficult to eliminate. Rain-water shaken vigorously with air in a partially filled bottle for hours retains it almost, if not quite, unimpaired. None of the chemical processes of purification previously described appear at all satisfactory. Permanganate of potassium is most disappointing in this connection. If enough is added to give a faint pink tinge persisting for several minutes, the taste is seldom abolished and may hardly be even modified. If more is added, a permanganate taste is acquired which is, if anything, worse. Even when a large excess is added

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and then after twenty-four hours' contact the excess removed by means of sodium sulphite, the results are disappointing. Slow sand filtration may improve matters very slightly, but slow filtration through charcoal is much more effective. Alternatively, wood charcoal powder may be added to the water, the mixture well stirred and then aluminium sulphate added as a coagulant. Both the charcoal and alumina are precipitated. As regards amounts, 20 grains per gallon of wood charcoal powder may suffice, but in obstinate cases it may be necessary to increase the dose greatly— *it may be even tenfold*. The aluminium sulphate, if lime has been used as the bactericidal agent, may be added in amount sufficient to neutralize the excess CaO (3·96, say 4, grains of aluminium sulphate for each grain of CaO). If this does not produce a good precipitate, more may be used up to a total of say 6 grains per gallon, care being taken to add sodium carbonate as well in the proportion of 1·29 (say 1·3) grains of sodium carbonate crystals for each grain of aluminium sulphate used in excess of that portion required for neutralization of the excess lime (CaO). If the settled liquid is unsightly, due to imperfect settlement of the charcoal, it should be filtered. In the writer's experience, the *worst cases of taste can be cured* by the foregoing method. If a slight super-dose of chlorine (say 1 in 1 million) is added to rainwater, the liquid usually acquires a chlorinous taste,

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which may *mask* the sooty flavour, but is perhaps equally if not more unpleasant. If enough sodium sulphite is added to remove the excess of chlorine, the chlorinous taste may disappear, but the sooty flavour is apt to become again noticeable. The "after-taste" of stale chlorinated waters does not seem to lend itself readily to remedial treatment.

If a very strong super-dose of chlorine is tried and then the excess chlorine removed by means of sulphites, the chlorinous taste vanishes but the sooty taste still persists.

*Wells and Springs.*—These waters are usually highly palatable, although in the former case the water may be derived from most doubtful sources of supply. Slow passage through the soil, oxidation processes, and solution of various soluble salts and gases give to well waters a most acceptable " bite " and flavour.

*Brooks and Burns.*—These are usually well flavoured, although when very soft and peaty, the taste is an acquired one.

*Rivers.*—Much the same may be said of rivers, although in stagnant "reaches" a great development of plant and animal life may occur. These, by their decomposition and the setting free of oily matters and offensive gases, may give rise to a variety of most unpleasant tastes and odours.

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*Lakes, Lochs and Reservoirs* are generally pleasant to drink, but are liable, seasonably or occasionally, to active algal growths which may render the water temporarily almost undrinkable. It is curious that potassium permanganate, so disappointing in the case of rain-water, is almost a specific[1] for this trouble in doses of 0·5 part per million parts. The writer has not found chlorine preparations satisfactory in this connection. Some aquatic plants (e.g., chara) give rise to most offensive tastes and odours as do some animals (e.g., the sponges). Figs. 10 and 11 (for description, *see* p. xv.) illustrate some of the growths associated with taste troubles.

Of course, the writer is here dealing with ordinary, not exceptional supplies.

Deep wells may sometimes have a most unpleasant taste due to the presence of iron and sulphuretted hydrogen. Aeration and filtration usually remove these troubles. Some springs contain so much iron as to be called "ochre springs." Again, some surface and deep supplies may contain so high a proportion of chlorides, sulphates, &c., as to be practically undrinkable. Lastly, there are medicinal springs which, owing to their taste and purgative action, could only be tolerated for curative purposes. These, however,

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[1] *See* p. 100, " Studies in Water Supply " (Messrs. Macmillan and Co.).
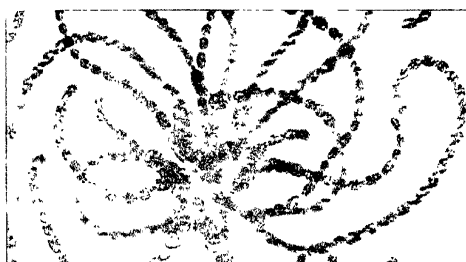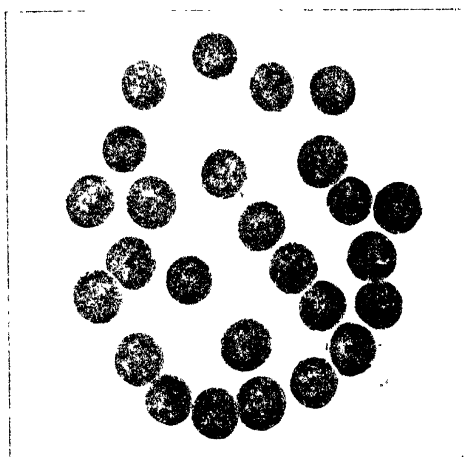
(A) Stephanodiscus × 400.
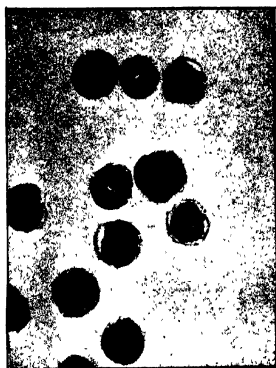
(B) Glenodinium, × 150.
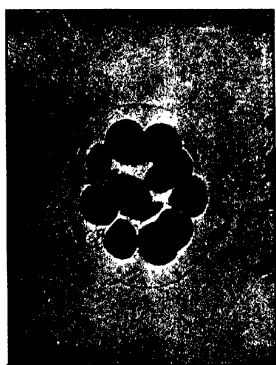
(C) Pandorina, × 400.
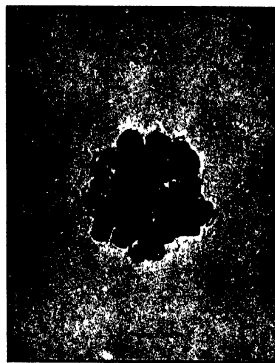
(D) Synura, × 4co.

FIG. 11.

are exceptional waters, which lie outside the purview of this treatise.

In conclusion, the chief points to be noted are as follows :—

All surface sources of water supply, even if normally free from the taint of sewage pollution, are open to accidental contamination.

In selecting a method of treatment, consider in the first place safety from disease and then questions of clarification, softening, taste, &c. (*see* Tables XII., XV., and XVI. and Miscellaneous Experiments, p. 98).

Never forget the importance of a topographical survey of the source of any water supply.

It is sometimes easy, at other times very difficult, to remove the taste from waters having an un-pleasant flavour. Aeration, filtration and the use of permanganate of potassium and charcoal (*see* p. 64) are all of value in particular cases. A chlorinous taste, due to active chlorine, may be removed by means of sulphites, &c., but the after-taste of a stale chlorinated water is less amenable to treat-ment. If strong doses of either permanganate or chlorine are added to rain-water, the excess being subsequently neutralized, the permanganate or chlorinous taste may disappear, but the sooty flavour is apt to become prominent again.

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Consideration will now be given to the results of actual experiments on the sterilization and purification of rain-water, &c. The reader will thus be able to judge how far practice agrees with theory. It is hoped that the examples given will stimulate the novice to become, if not a water expert, at all events a convert to the belief that nearly all waters may be purified to any standard of safety required.

The writer obviously cannot hope to render matters which are intrinsically difficult to the trained expert transparently simple to the average reader. His hope lies in stimulating interest, and in affording information to those who, with or without further advice, are determined to advance their knowledge of rural water supplies. (*See* concluding remarks on p. 128.)

# CHAPTER VI.

## THE RESULTS OF ACTUAL EXPERIMENTS.

Series I. Sterilization of rain-water with bleach solution.—
Series II. Sterilization of rain-water by means of lime.
—Series III. Purification, clarification and softening of
impure river-water by means of lime, aluminium
sulphate and sodium carbonate.—Series IV. (I., II.,
and III.). Experiments in Series I., II., and III.
repeated on a confirmatory *B. coli* basis.—Series V.
Lime, time and sterilization.—Concluding remarks
(p. 88).

There is nothing quite so convincing as the
results of actual experiments, and the following
notes are given as examples of the sterilization
and purification of various kinds of water by one
or other of the methods previously described.

## SERIES I.[1]

### *The Sterilization of Town Rain-water by means of Bleaching Powder Solution.*

The dose, in terms of available chlorine, was
(*a*) 1 in 1 million, (*b*) 1 in 2 millions, and (*c*) 1 in

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[1] In Series I., II., III., a war brand of bile-salt medium was
used which proved unsatisfactory from the point of view of
presumptive *B. coli* results. In all the other experiments
confirmatory tests were applied.

4 millions. This is equal in grains per gallon to (*a*) 0·07, (*b*) 0·035, and (*c*) 0·0175. With bleaching powder of 33 per cent. strength the amount of actual substance would be (*a*) 0·21, (*b*) 0·105, and (*c*) 0·0525. The rain-water was first purposely inoculated with a little fresh human fæces and then examined bacteriologically for *B. coli;* 500 c.c. (17·65 ozs.) of the sample were next poured into each of three stoppered bottles and chlorine added in the doses already stated. It may be desirable to explain to the non-expert reader the reason why the *B. coli* test is applied in these cases. Excremental matters contains *B. coli* in enormous numbers, and although the ordinary fæcal type of *B. coli* is believed to be relatively or absolutely harmless, its presence in any number in a water is presumptive evidence of potential danger to health, because, if the pollution is of human origin, *B. coli* is liable at any time to be accompanied by bacteria which are unquestionably pathogenic (e.g., the typhoid bacillus). Add to this the fact that *B. coli* is a more hardy germ than the typhoid bacillus and it becomes at once apparent that a sterilization process which rids a water of *B. coli* is unquestionably safe as regards · the microbes of epidemic water-borne disease (e.g., typhoid fever).

*Experiment* 1.—After inoculation, the rain-water contained *B. coli* in 0·01, but not in 0·001 c.c.

After eight and twenty-four hours, *B. coli* tests were again made with the following results :—

### After eight hours.

(*a*) + 100 − 10 c.c.   (*b*) + 100 − 10 c.c.   (*c*) + 100 − 10 c.c.[1]

### After twenty-four hours.

(*a*) − 100 c.c.   (*b*) − 100 c.c.   (*c*) + 100 − 10 c.c.

It is apparent that after eight hours the improvement, bacteriologically, was 10,000 times even with the smallest dose (1 in 4 millions).

In twenty-four hours, the improvement was at least 100,000 times in (*a*) and (*b*) and 10,000 times in (*c*).

*Experiment* 2.—After inoculation, the rain-water contained *B. coli* in 0·01, but not 0·001 c.c. The results, after eight and twenty-four hours, were exactly the same as in Experiment 1 except that in twenty-four hours (*b*) as well as (*c*) contained *B. coli* in 100 c.c.

*Experiment* 3.—After inoculation, the rain-water contained *B. coli* in 0·0001, but not 0·00001 c.c.

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[1] Note that + = positive result (or present in), and − = negative result (or absent from), the amount of water stated.

## After eight hours.

| (*a*) + 10 c.c. | (*b*) + 10 c.c. | (*c*) + 1 c.c. |
|---|---|---|
| − 1 c.c. | − 1 c.c. | − 0˙1 c.c. |
| (Improved 100,000 times) | (Improved 100,000 times) | (Improved 10,000 times) |

## After twenty-four hours.

| (*a*) − 100 c.c. | (*b*) + 100 c.c. | (*c*) + 10 c.c. |
|---|---|---|
| | − 10 c.c. | − 1 c.c. |
| (Improved at least 10 million times) | (Improved 1 million times) | (Improved 100,000 times |

*Experiment* 4.—After inoculation, the rain-water contained *B. coli* in 0˙01, but not 0˙001 c.c. The results, after eight and twenty-four hours, were exactly the same as in Experiment 2.

*Experiment* 5.—After inoculation, the rain-water contained *B. coli* in 0˙01, but not 0˙001 c.c. The results, after eight and twenty-four hours, were exactly the same as in Experiment 1 except that in twenty-four hours (*c*) as well as (*a*) and (*b*) contained no *B. coli* in 100 c.c.

*Experiment* 6.—After inoculation, the rain-water contained *B. coli* in 0˙1, but not 0˙01 c.c. The results, both after eight and twenty-four hours, were the same in each case, namely, 10 c.c. − 1 c.c. The improvement was thus 100 times.

*Experiment* 7.—After inoculation, the rain-water contained *B. coli* in 0˙01, but not 0˙001 c.c.

After both eight and twenty-four hours, the results were :—

(*a*) + 100 – 10 c.c. ; (*b*) + 1 – 0˙1 c.c. ; (*c*) + 0˙1 – 0˙01 c.c. The improvement was (*a*) 10,000 times ; (*b*) 100 times, and (*c*) 10 times.

*Experiment* 8.—After inoculation, the rain-water contained *B. coli* in 0˙01, but not 0˙001 c.c. The results, both after eight and twenty-four hours, were as follows :—

(*a*) – 100 c.c.; (*b*) + 10 – 1 c.c.; (*c*) + 1 – 0˙1 c.c. The improvement was thus (*a*) at least 100,000 times ; (*b*) 1,000 times ; and (*c*) 100 times.

*Experiment* 9.—After inoculation, the rain-water contained *B. coli* in 0˙001, but not 0˙0001 c.c. The results were as under :—

After eight hours.

(*a*) + 100 – 10 c.c. ; (*b*) + 10 – 1 c.c. ; (*c*) + 10 – 1 c.c. The improvement was thus (*a*) 100,000 times ; (*b*) and (*c*) 10,000 times.

After twenty-four hours.

(*a*) – 100 c.c. ; (*b*) + 100 – 10 c.c. ; (*c*) + 100 – 10 c.c. The improvement was thus (*a*) at least 1 million times, (*b*) and (*c*) 100,000 times.

It is worth noting that the samples of rain-water in Experiments 6 and 7 were, quite apart from the artificial fæcal contamination, extremely dirty.

A parallel series of experiments were carried out, but without the addition of fæces, for judging questions of taste.

All the samples had a sooty taste before the addition of the bleach solution.

After twenty-four hours they either had a chlorinous or a combined chlorinous and sooty, or a sooty taste only. The addition of sodium sulphite to those giving a chlorinous taste was of use inasmuch as it removed the chlorinous taste, but the sooty taste remained quite appreciable.

The chief bacteriological results are set forth in the table on next page.

The results show that with a very dirty sample of rain-water a dose of 1 in 1 million with twenty-four hours' contact is hardly sufficient (on a presumptive basis), but with a very good sample 1 in 4 millions may actually suffice. Practically, a dose of 1 in 2 millions would probably be ample in the great majority of cases.

It should also be noted that the positive *B. coli* results were based on a presumptive basis.[1] Experience has shown that presumptive results may be sometimes misleading, because the positive

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[1] *Presumptive* = acid and gas formation in the 'lactose' bile-primary medium. *Confirmatory* = isolation of a " lactose + indol + " microbe.

## THE RESULTS OF ACTUAL EXPERIMENTS

TABLE X. — The Sterilization of Rain-water with Bleach Solution. Dose: (a) 1 in 1 million, (b) 1 in 2 millions, (c) 1 in 4 millions, in Terms of Available Chlorine.

| Experiment | Smallest amount (in c.c.) of water yielding a positive B. coli result after inoculation, but before addition of chlorine | Same as Col. 2, but after eight hours of chlorine treatment. (See, however, remarks at end of Series I.) | Improvement after eight hours (times) | Same as Col. 2, but after twenty-four hours' chlorine treatment (See, however, remarks at end of Series I.) | Improvement after twenty-four hours (times) |
|---|---|---|---|---|---|
| Cols. 1 | 2 | 3 | 4 | 5 | 6 |
| 1a | + 0·01 | + 100 | 10,000 | None in 100 | 100,000 (at least) |
| 1b· | ,, | ,, | ,, | ,, | 100,000 |
| 1c | ,, | ,, | ,, | + 100 | 10,000 |
| 2a | + 0·01 | + 100 | 10,000 | None in 100 | 100,000 (at least) |
| 2b | ,, | ,, | ,, | + 100 | 10,000 |
| 2c | ,, | ,, | ,, | ,, | ,, |
| 3a | + 0·0001 | + 10 | 100,000 | None in 100 | 10,000,000 (at least) |
| 3b | ,, | ,, | ,, | + 100 | 1,000,000 |
| 3c | ,, | + 1 | 10,000 | + 10 | 100,000 |
| 4a | + 0·01 | + 100 | 10,000 | None in 100 | 100,000 (at least) |
| 4b | ,, | ,, | ,, | + 100 | 10,000 |
| 4c | ,, | ,, | ,, | ,, | ,, |
| 5a | + 0·01 | + 100 | 10,000 | None in 100 | 100,000 (at least) |
| 5b | ,, | ,, | ,, | ,, | 100,000 |
| 5c | ,, | ,, | ,, | ,, | ,, |
| 6a | + 0·1 | + 10 | 100 | + 10 | 100 |
| 6b | ,, | ,, | ,, | ,, | ,, |
| 6c | ,, | ,, | ,, | ,, | ,, |
| 7a | + 0·01 | + 100 | 10,000 | + 100 | 10,000 |
| 7b | ,, | + 1 | 100 | + 1 | 100 |
| 7c | ,, | + 0·1 | 10 | + 0·1 | 10 |
| 8a | + 0·01 | None in 100 | 100,000 (at least) | None in 100 | 100,000 (at least) |
| 8b | ,, | + 10 | 1,000 | + 10 | 1,000 |
| 8c | ,, | + 1 | 100 | + 1 | 100 |
| 9a | + 0·001 | + 100 | 100,000 | None in 100 | 1,000,000 (at least) |
| 9b | ,, | + 10 | 10,000 | + 100 | 100,000 |
| 9c | ,, | + 10 | ,, | ,, | ,, |

result obtained may be more apparent than real. That is, that acid and gas may show in the primary bile-salt medium[1] and yet on subculture no growths occur, or a growth of microbes other than *B. coli*. It is possible or even probable that the results would have been completely satisfactory[2] if they had been based on confirmatory instead of presumptive evidence. These remarks also apply to Series II. and III.

## SERIES II.

### *The Sterilization of Town Rain-water by means of Lime.*

The rain-water was first purposely inoculated with a little fresh human fæces and then examined bacteriologically. Then 2 grains of hydrate of lime (CaO, $H_2O$) were added to 48 ounces ($=$ about 6·7 grains per gallon) of the fæcally contaminated water and cultures made after eight and twenty-four hours on the *shaken* sample. Before shaking, however, a little of the clear liquid was withdrawn to estimate the amount of lime (CaO) left over in excess.

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[1] This remark, however, does not apply, or only to a very modified extent, to the bile-salt media of pre-war days. Then a presumptive result (if at all decided) was nearly always confirmed on subculture. Now with the current brands of bile-salt, the results, in the writer's experience, are much less to be trusted.

[2] Reference to Series IV. (I., II., and III.) will show the correctness of this assumption.

The method of determining the excess lime has already been described (see pp. 16, 55).

The chief results are set forth in the accompanying table :—

TABLE XI.—The Sterilization of Rain-water with Lime. Two GRAINS OF HYDRATE OF LIME (CaO, H₂O IN 48 OZ. (= ABOUT 6·7 GRAINS PER GALLON).

| Experiment | Smallest amount (in c.c.) of water yielding a positive B. coli result after inoculation, but before addition of lime | Same as Col. 2, but after eight hours of lime treatment. (See, however, notes at end of Series I.) | Improvement after eight hours. (Times) | Same as Col. 2, but after twenty-four hours of lime treatment. (See, however, notes at end of Series I.) | Improvement after twenty-four hours. (Times) | Actual excess of caustic lime (CaO) in the water in grains per gallon |
|---|---|---|---|---|---|---|
| Cols. 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 1 | + 0·001 | + 10 | 10,000 | + 100 | 100,000 | 2·4 |
| 2 | + 0·01 | + 10 | 1,000 | + 10 | 1,000 | 3·5 |
| 3 | + 0·01 | + 100 | 10,000 | + 100 | 10,000 | 4·3 |
| 4 | + 0·0001 | + 10 | 100,000 | + 10 | 100,000 | 3·4 |
| 5 | + 0·01 | + 10 | 1,000 | + 10 | 1,000 | 4·5 |
| 6 | + 0·01 | + 100 | 10,000 | + 100 | 10,000 | 4·5 |
| 7 | + 0·1 | + 10 | 100 | + 100 | 1,000 | 3·5 |
| 8 | + 0·01 | + 10 | 1,000 | + 100 | 10,000 | 3·2 |
| | | | | | | Average about 3·7 |

It is apparent from the table that a dose of 6 to 7 grains per gallon of hydrate of lime (CaO, H₂O), leaving in the water an excess of caustic lime (CaO) of about 3 to 4 grains, can improve to a remarkable extent bacteriologically, in from eight to twenty-four hours, an artificially fæcally contaminated rain-water. A somewhat larger dose than was here employed is needed to sterilize the water absolutely (as judged by presumptive results), but

it is obvious from the table that the results obtained were so good as only to miss perfection by a narrow margin.

The bacteriological cultures were made on "shaken" samples (i.e., so as to include the sediment).

In practice, however, the deposit would not be drunk, and human fæcal contamination of rain-water is most unlikely to take place, and never to the extent here artificially produced. *See*, however concluding remarks under Series I., which indicate that much better results would probably have been obtained if confirmatory tests had been applied, or a pre-war brand of bile-salt used in preparing the medium.

## SERIES III.

*The Purification, Clarification, and Softening of an Impure River Water by means of Lime, Aluminium Sulphate and Sodium Carbonate.*

The water was first examined for *B. coli* and for hardness and colour. Then 9 grains of calcium hydrate (CaO, $H_2O$) were added to 80 ounces contained in a stoppered bottle, this being judged to be about the amount necessary to neutralize the dissolved $CO_2$ and bicarbonates in the water and yet leave enough caustic lime (CaO) in excess to effect sterilization. After vigorous shaking the mixture was left for twelve hours. Next, a little

was withdrawn and used to estimate the excess
lime (CaO). The bottle was then shaken and
further *B. coli* cultures made so as to estimate the
improvement bacteriologically. Then 40 ounces
were poured into a bottle and first 3 grains of
aluminium sulphate and then 7·5 grains of sodium
carbonate were dissolved in the water, it being
judged that these amounts would serve to neutralize
the excess of lime and clarify and soften the water.
After settlement the clear liquid was examined for
colour and hardness.

The chief results are shown in the accompanying
table (Table XII.).

It will be seen that the chemical results were
very satisfactory, the colour and hardness being
reduced on the average 65 per cent. and 79 per
cent. respectively.

Bacteriologically, a great improvement was
effected, although evidently a slightly larger dose
·of lime, or a longer contact, was required to produce
entirely satisfactory results (on a presumptive basis).
*See*, however, concluding remarks under Series I.,
which indicate that much better results would
probably have been obtained if confirmatory tests
had been applied, or a pre-war brand of bile-salt
used in preparing the medium.

## SERIES IV.

In order to clear up the point as to whether the
results in Series I., II., and III. would not have

TABLE XII.—THE PURIFICATION, CLARIFICATION AND SOFTENING OF IMPURE RIVER WATER BY MEANS OF LIME. HYDRATE OF LIME (CaO, H₂O) 9 GRAINS PER 80 OZ. (= 18 GRAINS PER GALLON). ALUMINIUM SULPHATE AND SODIUM CARBONATE SUBSEQUENTLY ADDED IN THE PROPORTION OF 3 AND 7·5 GRAINS RESPECTIVELY PER 40 OZ. OF THE LIME-TREATED WATER (= 12 AND 30 GRAINS PER GALLON).

| Experiment | Smallest amount of water (in c.c.) yielding a positive B. coli result. (See, however, notes at end of Series I.) | Colour (m.m. brown, 2 feet tube) | Total hardness (grains per gallon) | Actual excess of caustic lime (CaO) in the water in grains per gallon, before adding the al. sulph. |
|---|---|---|---|---|
| Cols. 1 | 2 | 3 | 4 | 5 |
| Experiment 1— | | | | |
| Before treatment | + 0·01 | 82 | 16·5 | — |
| After treatment... | + 100 | 26 | 3·2 | 4·3 |
| | (Improved 10,000 times) | (68 per cent. reduction) | (80 per cent. reduction) | |
| Experiment 2— | | | | |
| Before treatment | + 0·1 | 76 | 17·3 | — |
| After treatment ... | + 10 | 30 | 3·8 | 5·0 |
| | (Improved 100 times) | (60 per cent. reduction) | (78 per cent. reduction) | |
| Experiment 3— | | | | |
| Before treatment | + 0·01 | 84 | 17·0 | — |
| After treatment... | + 10 | 26 | 4·0 | 4·1 |
| | (Improved 1,000 times) | (69 per cent. reduction) | (76 per cent. reduction) | |
| Experiment 4— | | | | |
| Before treatment | + 0·1 | 80 | 19·3 | — |
| After treatment... | + 100 | 24 | 4·0 | 4·3 |
| | (Improved 1,000 times) | (70 per cent. reduction) | (79 per cent. reduction) | |
| Experiment 5— | | | | |
| Before treatment | + 0·1 | 54 | 19·1 | — |
| After treatment... | + 100 | 23 | 3·8 | 3·8 |
| | (Improved 1,000 times) | (57 per cent. reduction) | (80 per cent. reduction) | |
| Experiment 6— | | | | |
| Before treatment | + 0·01 | 60 | 19·3 | — |
| After treatment... | + 10 | 24 | 3·8 | 4·5 |
| | (Improved 1,000 times) | (60 per cent. reduction) | (80 per cent. reduction) | |
| | | (65 per cent. on the average) | (79 per cent. on the average) | 4·34 (average) |

been still better if *confirmatory B. coli* tests had
been applied, a further set of experiments were
undertaken.

## RAIN-WATER.—SERIES IV. (I.).

*This corresponds with Series I., except that the
B. coli results were based on confirmatory
evidence.*

TABLE XIII.—COMPARE WITH TABLE X.

DOSE (*a*) 1 IN 1 MILLION, (*b*) 1 IN 2 MILLIONS, (*c*) 1 IN 4 MILLIONS,
IN TERMS OF AVAILABLE CHLORINE.

| Experiment | Smallest amount (in c.c.) of water yielding a positive *B. coli* result, after inoculation, but before addition of chlorine | Same as Col. 2, but after eight hours of chlorine treatment | Same as Col. 2, but after twenty-four hours of chlorine treatment |
|---|---|---|---|
| Cols. 1 | 2 | 3 | 4 |
| 1*a* | + 0·01 c.c. | + 10 c.c. | + 100 c.c. |
| 1*b* | ,, | + 1 ,, | + 1 ,, |
| 1*c* | ,, | + 0·1 ,, | + 0·1 ,, |
| 2*a* | + 0·01 c.c. | + 0·1 c.c. | + 1 c.c. |
| 2*b* | ,, | ,, | + 0·1 ,, |
| 2*c* | ,, | ,, | + 0·1 ,, |
| 3*a* | + 0·01 c.c. | + 10 c.c. | + 10 c.c. |
| 3*b* | ,, | + 1 ,, | + 0·1 ,, |
| 3*c* | ,, | + 0·1 ,, | + 0·1 ,, |
| 4*a* | + 0·001 c.c. | − 100 c.c. | − 100 c.c. |
| 4*b* | ,, | ,, | − 100 ,, |
| 4*c* | ,, | + 100 c.c. | + 100 ,, |
| 5*a* | + 0·1 c.c. | − 100 c.c. | − 100 c.c. |
| 5*b* | ,, | ,, | ,, |
| 5*c* | ,, | ,, | ,, |

The first three samples of rain-water, as it turned
out, happened to be very dirty, and, although an
improvement was effected even with the minimum

dose, the maximum dose failed to produce complete sterilization.

With the last two samples completely satisfactory results were obtained with the middle dose of 1 in 2 millions in the first experiment and with the minimum dose of 1 in 4 millions in the last experiment. For all ordinary samples of rain-water a dose of 1 in 2 millions would probably be quite safe.

## SERIES IV. (II.).

*This corresponds with Series II., except that the B. coli results were based on confirmatory evidence.*

TABLE XIV.—COMPARE WITH TABLE XI.

RAIN-WATER. TWO GRAINS OF HYDRATE OF LIME (CaO, H$_2$O) IN 48 OZ. (= ABOUT 6·7 GRAINS PER GALLON).

| Experiment | Smallest amount (in c.c.) of water yielding a positive *B. coli* result, after inoculation, but before addition of lime | Same as Col. 2, but after eight hours of lime treatment | Same as Col. 2, but after twenty-four hours of lime treatment | Actual excess of caustic lime (CaO) in the water in grains per gallon |
|---|---|---|---|---|
| Cols. 1 | 2 | 3 | 4 | 5 |
| 1 | + 0·01 c.c. | + 100 c.c. | − 100 c.c. | 3·0 |
| 2 | + 0·001 ,, | − 100 ,, | ,, | 2·3 |
| 3 | + 0·1 ,, | − 100 ,, | ,, | 2·5 |

The results seem to show conclusively that a dose of about 6·7 grains of calcium hydrate (CaO, H$_2$O) per gallon of rain-water would be perfectly safe as regards sterilization.

## Series IV. (III.).

*This corresponds with Series III., except that the*
*B. coli results were based on confirmatory*
*evidence, and questions of hardness and colour*
*were not again considered.*

TABLE XV.—Compare with Table XII.

River-water. Hydrate of Lime (CaO, $H_2O$) 9 grains per
80 oz. (= 18 grains per gallon.)

| Experiment | Smallest amount of water (in c.c.) yielding a positive B. coli result, before addition of lime | Same as Col. 2, but after twelve hours' lime treatment | Actual excess of caustic lime (CaO) in the water in grains per gallon |
|---|---|---|---|
| Cols. 1 | 2 | 3 | 4 |
| 1 | ... + 0·1 c.c. ... | − 100 c.c. | 1·4 |
| 2 | ... + 0·1 ,, ... | ,, | 2·8 |
| 3 | ... + 0·01 ,, ... | ,, | ,, |

The results show clearly that a dose sufficient
to leave less than 3 grains of excess lime (CaO)
in the treated water is more than enough for
sterilization purposes.

Speaking generally, the assumption that the good
results obtained in Series I., II., and III. would have
been better still if *confirmatory B. coli* tests had
been applied is completely borne out by the results
set forth in Series IV. (I., II., and III.).

## SERIES V.

### *Lime, Time and Sterilization.*

It will be remembered that in Chapter II. it was pointed out that the dose of lime for sterilization purposes could be very greatly reduced by prolonging the contact for several days.

The following experiments serve to emphasize this point :—

*Experiment* 1.—Rain-water : Lime added in such proportion as to leave an excess (CaO) of 2·1 grains per gallon. Inoculated with fresh human fæces. Initial *B. coli* determination (+ 0·001 c.c.) After twenty-four hours, no *B. coli* even in 100 c.c.

*Experiment* 2.—Same as Experiment 1. Initial *B. coli* determination (+ 0·01 c.c.). Excess lime (CaO) 1·9 grains per gallon. After twenty-four hours, no *B. coli* even in 100 c.c.

*Experiment* 3.—Same as Experiment 1. Initial *B. coli* determination (+ 0·01 c.c.). Excess lime (CaO) 2·6 grains per gallon. After twenty-four hours, no *B. coli* even in 100 c.c.

*Experiment* 4.—Same as Experiment 1. Initial *B. coli* determination (+ 0·0001 c.c). Excess lime (CaO) 0·7 grain per gallon. After twenty-four hours, no *B. coli* even in 100 c.c.

*Experiment* 5.—Same as Experiment 1. Initial *B. coli* determination (+ 0·001 c.c.). Excess lime

(CaO) 0·4 grain per gallon. After twenty-four hours, no *B. coli* even in 100 c.c.

*Experiment* 6.—Same as Experiment 1. Initial *B. coli* determination (+ 0·001 c.c.). Excess lime (CaO) 0·3 grain per gallon. After twenty-four hours, no *B. coli* even in 100 c.c.

*Experiment* 7.—Same as Experiment 1. Initial *B. cbli* determination (+ 0·001c.c.). Excess lime (CaO) 0·1 grain per gallon. After twenty-four hours, *B. coli* present in 10 c.c. After forty-eight hours, no *B. coli* even in 100 c.c.

*Experiment* 8.—Same as Experiment 1. Initial *B. coli* determination (+ 0·001 c.c.). Excess lime (CaO) 0·2 grain per gallon. After twenty-four hours, *B. coli* present in 100 c.c. After forty-eight hours, no *B. coli* even in 100 c.c.

*Experiment* 9.—In this experiment an impure river-water (no artificial contamination was made) was substituted for rain-water. Initial *B. coli* determination (+ 0·01 c.c). Lime added in such proportion as to leave an excess of 2·4 grains (CaO) per gallon. After twenty-four hours, no *B. coli* even in 100 c.c.

*Experiment* 10.—Same as Experiment 9. Initial *B. coli* determination (+ 0·1 c.c.). Excess lime (CaO) 1·2 grains per gallon. After twenty-four hours, no *B. coli* even in 100 c.c.

*Experiment* 11.—Same as Experiment 9. Initial *B. coli* determination (+ 0·01 c.c.). Excess lime

(CaO) 0·6 grain per gallon. After twenty-four hours, *B. coli* present in 100 c.c. After forty-eight hours, no *B. coli* even in 100 c.c.

*Experiment* 12.—Conditions same as in Experiment 1 (rain-water). Initial (i.e., after inoculation) *B. coli* determination (+ 0·1 c.c.). Excess lime (CaO) 0·1 grain per gallon. After twenty-four hours, *B. coli* present in 1 c.c. After forty-eight hours, *B. coli* present in 100 c.c. After seventy-two hours, no *B. coli* even in 100 c.c.

*Experiment* 13.—Conditions same as in Experiment 1. Initial *B. coli* determination (+ 0·1 c.c.) Excess lime (CaO) 0·1 grain per gallon. After twenty - four hours, *B. coli* present in 100 c.c. After forty-eight hours, *B. coli* present in 100 c.c. After seventy-two hours, no *B. coli* even in 100 c.c.

TABLE XVI.—LIME, TIME AND STERILIZATION.

| Experiment | Excess lime (CaO) in grains per gallon | Initial *B. coli* result | When *B. coli* was killed |
|---|---|---|---|
| 1 | 2·1 | + 0·001 c.c. | Within twenty-four hours |
| 2 | 1·9 | + 0·01 ,, | ,, ,, |
| 3 | 2·6 | + 0·01 ,, | ,, ,, |
| 4 | 0·7 | + 0·0001 ,, | ,, ,, |
| 5 | 0·4 | + 0·001 ,, | ,, ,, |
| 6 | 0·3 | + 0·001 ,, | ,, ,, |
| 7 | 0·1 | + 0·001 ,, | Within forty-eight hours |
| 8 | 0·2 | + 0·001 ,, | ,, ,, |
| 9 | 2·4 | + 0·01 ,, | Within twenty-four hours |
| 10 | 1·2 | + 0·1 ,, | ,, ,, |
| 11 | 0·6 | + 0·01 ,, | Within forty-eight hours |
| 12 | 0·1 | + 0·1 ,, | Within seventy-two hours |
| 13 | 0·1 | + 0·1 ,, | ,, ,, |
| 14 | 0·2 | + 0·1 ,, | ,, ,, |

*Experiment* 14.—Conditions same as in Experiment 1. Initial *B. coli* determination (+ 0·1 c.c.). Excess lime (CaO) 0·2 grain per gallon. After twenty-four hours, *B. coli* present in 10 c.c. After forty-eight hours, *B. coli* present in 100 c.c. After seventy-two hours, no *B. coli* even in 100 c.c.

The chief results are tabulated in Table XVI.

It is apparent that some waters at all events may be sterilized with very minute traces of lime (in *excess*) provided the contact is not less than from one to three days. It does not follow, however, that all waters will behave in a precisely similar manner (especially as some absorption of $CO_2$ from the air would take place), and in practice it would be unsafe to rely on these fractional doses, unless the treatment was kept under scientific observation. Nevertheless, the results do indicate that if rain-water is so reasonably free from colour, taste and suspended matter as not to call for any special treatment, and if it can be stored for several days, lime treatment presents remarkable advantages. For example, the dose required for sterilization purposes is so small as not to require any neutralization subsequently, and, of course, a water treated in this way could not possibly have any taste of lime and would be innocuous in all respects. In the case of really hard waters, however, this "small dose and long contact" method of treatment is less attractive, for the reason that any slight increase in the

temporary hardness might more than rob the treated water of any excess of lime (CaO), and in so doing destroy its bactericidal action.

In conclusion, the chief points to be noted are as follows :—

With reasonably pure samples of rain-water a dose of 1 in 2 millions (in terms of available chlorine), acting for eight to twenty-four hours, is amply sufficient for sterilization purposes (Series I., also Series IV. (I.)).

Rain-water may be effectively sterilized with a dose of slaked lime (calcium hydrate) of, say, 6·7 (to provide a margin for safety) grains per gallon acting from eight to twenty-four hours (Series II., also Series IV. (II.)).

Hard impure river-water may be readily sterilized by means of lime if enough is added to leave over an excess of, say, 3 (to provide a margin for safety) grains of CaO per gallon. The excess lime (CaO) may be neutralized, and the water softened (reduction 79 per cent. in the experiments) and rendered less brown (reduction 65 per cent. in the experiments) by the addition subsequently of aluminium sulphate and sodium carbonate (Series III., also Series IV. (III.)).

Extremely small doses of lime (CaO) in *excess* (considerably less than 1 grain per gallon) are

capable of sterilizing rain-water and other waters, if the duration of contact is prolonged over several days (Series V.).

In the next chapter (so as to avoid over-burdening the present one) the results of further experiments on the purification of water will be given.
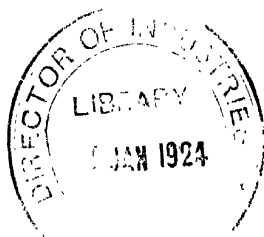
# CHAPTER VII.

## THE RESULTS OF ACTUAL EXPERIMENTS—
### (*Continued*).

Series VI. Lime and phosphate method of sterilization.—
Series VII. Sterilization and clarification of soft peaty
waters.—Series VIII. Lime and sodium bicarbonate
method of treatment.—Series IX. Miscellaneous experi-
ments.—Concluding remarks (p. 101).

### Series VI.

#### *Excess Lime and Sodium Hydrogen Phosphate Method of Purification.*

*Experiment* 1.—Forty-eight ounces of rain-water
were inoculated with fresh human fæces. The
initial *B. coli* determination was + 0·01 c.c. The
colour was 80 and the hardness 4·4 grains per
gallon. Three grains (= 10 grains per gallon) of
calcium hydrate (CaO, $H_2O$) were then added, the
mixture well shaken and the precipitate allowed to
settle. After twelve hours a little of the clear
liquid was withdrawn and the excess lime (CaO)
determined. It was equal to 7·2 grains per gallon.
After shaking, *B. coli* tests were made, but no
*B. coli* could be found even in 100 c.c. of the water.

Next, 24 ounces of the mixture were treated with 2·5 grains (= about 17 grains per gallon) of sodium hydrogen phosphate and then with 1 grain (= about 7 grains per gallon) of sodium bicarbonate. When the copious precipitate produced had been allowed to settle, the colour and hardness were found to be · 50 (reduction about 37 per cent.) and 5·2 respectively.

*Experiment 2.*—Same as Experiment 1. Initial *B. coli* determination (+ 0·001 c.c.), colour 150 and hardness 3·9 (grains per gallon). Three grains of calcium hydrate added to 48 ounces as before. After twelve hours, excess lime (CaO), 6·8 grains per gallon ; no *B. coli* even in 100 c.c. To 24 ounces of mixture 4·5 (= 30 grains per gallon) and 2·2 (= about 15 grains per gallon) of sodium hydrogen phosphate and sodium bicarbonate added, respectively. After settlement, colour and hardness 60 (reduction 60 per cent.) and 4·8 respectively.

*Experiment 3.*—Same as Experiment 1. Initial *B. coli* determination (+ 1 c.c.). Colour 84 and hardness 5·8 (grains per gallon). Here only 2 grains of calcium hydrate were added to 48 ounces of water (= about 6·7 grains per gallon). After twelve hours, excess lime (CaO) 1·7 grains per gallon ; no *B. coli* even in 100 c.c. To 24 ounces of mixture added 1·1 grain of sodium hydrogen phosphate and then 0·5 of sodium bicarbonate. After settlement,

colour and hardness determined and found to be
45 and 5·2 (grains per gallon) respectively.

The chief results may be tabulated as follows :—

TABLE XVII.—Rain-Water. Lime and Sodium Phosphate
Treatment.

| Experiment | Initial B. coli result | Initial colour | Initial hardness | Excess lime (CaO) | Final B. coli result | Final colour | Final hardness |
|---|---|---|---|---|---|---|---|
| 1 | + 0·01 c.c. | 80 | 4·4 | 7·2 | − 100 c.c. | 50 (about 37 per cent. reduction) | 5·2 |
| 2 | + 0·001 „ | 150 | 3·9 | 6·8 | „ | 60 (60 per cent. reduction) | 4·8 |
| 3 | + 1 „ | 84 | 5·8 | 1·7 | „ | 45 (about 46 per cent. reduction) | 5·2 |

It will be seen that an excess of lime (CaO) of less
than 2 grains per gallon (Experiment 3) sufficed
for sterilization purposes. The colour was also
considerably reduced. The hardness was higher
in the first two experiments, where the dose of lime
was somewhat large, but in the last experiment
there was a slight reduction in the hardness as a
result of the treatment.

Some authorities object to the use of phosphates
as precipitants, as phosphates tend to encourage
bacterial growths. The writer thinks that the
importance of this matter has been exaggerated, as
the only microbes likely to be affected would be
harmless water bacteria.

## SERIES VII.

### *The Sterilization and Clarification of a Soft Peaty Moorland Water.*

As a matter of fact, the water in question contained very few *B. coli*, so it was first inoculated with a trace of fresh human fæces, so as to see what would take place in the case of peaty waters exposed to excremental pollution. The *B. coli*, colour, and hardness results were then determined.

(*A*) Eighty ounces then received 3·35 grains (= 6·7 grains per gallon) of calcium hydrate (CaO, $H_2O$). The mixture was well shaken and then allowed to settle. After twelve hours, a little of the clear liquid was withdrawn for estimation of the excess lime (CaO). After shaking, *B. coli* cultures were made. Then 40 ounces of the mixture were treated with aluminium sulphate and sodium carbonate, and the colour and hardness results re-determined.

(*B*) Five hundred cubic centimetres (about 17·65 ounces) of the water were placed in each of three bottles, and these received bleach solution in doses (in terms of available chlorine) of (*a*) 1 in 1 million, (*b*) 1 in 2 millions, and (*c*) 1 in 4 millions. After seventeen hours, *B. coli* cultures were made.

*Experiment* 1.—Initial *B. coli* result (+ 0·1 c.c.). Colour 120. Hardness 3·4 (grains per gallon).

(*A*) Excess lime (CaO) 3·1. *B. coli* result, after twelve hours (– 100 c.c.). Forty ounces received 3·1 grains of aluminium sulphate and 4 grains of sodium carbonate. After settlement, colour 40, and hardness 8·0 (grains per gallon).

(*B*) After seventeen hours of chlorination, the results were as follows: (*a*) – 100 c.c.; (*b*) – 100 c.c.; (*c*) + 10 c.c.

*Experiment* 2.—Same as Experiment 1, except that less lime (2·5 grains) was used. Initial *B. coli* result (+ 0·001 c.c.). Colour 114; hardness 2·73.

(*A*) Excess lime (CaO) 2·0. *B. coli* results, after twelve hours (– 100 c.c.). Forty ounces received 1·96 grains of aluminium sulphate and 2·55 grains of sodium carbonate. After settlement, colour 60 and hardness 7·0.

(*B*) After seventeen hours of chlorination, the results were as follows: (*a*) + 100, not 10 c.c.; (*b*) + 100 and 10, not 1 c.c.; (*c*) + 100, 10 and 1, not 0·1 c.c.

*Experiment* 3.—Same as Experiment 2, 2·5 grains of lime being used. Initial *B. coli* result (+ 0·01 c.c.). Colour 110; hardness 2·5.

(*A*) Excess lime (CaO) 2·2. *B. coli* results after twelve hours (– 100 c.c.). Forty ounces received 2·18 grains of aluminium sulphate and 2·8 grains of

sodium carbonate. After settlement, colour 90 and hardness 8·26.

(*B*) After seventeen hours of chlorination, the results were as follows: (*a*) — 100 c.c.; (*b*) + 100 — 10 c.c.; (*c*) + 1 c.c. — 0·1 c.c. The chief results may be tabulated as follows :—

TABLE XVIII.—STERILIZATION AND CLARIFICATION OF MOORLAND WATERS.

| Experiment | Initial *B. coli* result | Initial colour | Initial hardness |
|---|---|---|---|
| 1 | + 0·1 c.c. | 120 | 3·4 |
| 2 | + 0·001 ,, | 114 | 2·73 |
| 3 | + 0·01 ,, | 110 | 2·5 |

| (A) Part of experiment | | | | (B) Part of experiment. Final *B. coli* result | | |
|---|---|---|---|---|---|---|
| Excess CaO | Final *B. coli* result | Final colour | Final hardness | (*a*) 1 in 1 million | (*b*) 1 in 2 millions | (*c*) 1 in 4 millions |
| 3·1 | — 100 c.c. | 40 | 8·0 | — 100 c.c. | — 100 c.c. | + 10 c.c. |
| 2·0 | ,, | 60 | 7·0 | + ,, | + 10 ,, | + 1 c.c. |
| 2·2 | ,, | 90 | 8·26 | — ,, | + 100 ,, | ,, |

As regards the *A* part of the experiment, it will be seen that an excess of 2 grains per gallon of CaO was quite effective bacteriologically. The water, however, was considerably harder after than before the treatment, and in the last experiment the reduction of colour was disappointing, looking as if the lime (CaO) had acted on the colouring matter in the water in some way so as to render

(*A*) Excess lime (CaO) 3·1. *B. coli* result, after twelve hours (− 100 c.c.). Forty ounces received 3·1 grains of aluminium sulphate and 4 grains of sodium carbonate. After settlement, colour 40, and hardness 8·0 (grains per gallon).

(*B*) After seventeen hours of chlorination, the results were as follows: (*a*) − 100 c.c.; (*b*) − 100 c.c.; (*c*) + 10 c.c.

*Experiment* 2.—Same as Experiment 1, except that less lime (2·5 grains) was used. Initial *B. coli* result (+ 0·001 c.c.). Colour 114; hardness 2·73.

(*A*) Excess lime (CaO) 2·0. *B. coli* results, after twelve hours (− 100 c.c.). Forty ounces received 1·96 grains of aluminium sulphate and 2·55 grains of sodium carbonate. After settlement, colour 60 and hardness 7·0.

(*B*) After seventeen hours of chlorination, the results were as follows: (*a*) + 100, not 10 c.c.; (*b*) + 100 and 10, not 1 c.c.; (*c*) + 100, 10 and 1, not 0·1 c.c.

*Experiment* 3.—Same as Experiment 2, 2·5 grains of lime being used. Initial *B. coli* result (+ 0·01 c.c.). Colour 110; hardness 2·5.

(*A*) Excess lime (CaO) 2·2. *B. coli* results after twelve hours (− 100 c.c.). Forty ounces received 2·18 grains of aluminium sulphate and 2·8 grains of

Next o·34 grain of sodium bicarbonate were added to 20 ounces of the mixture, and, after settlement, the hardness was determined and found to be 6·3 grains per gallon.

*Experiment* 2.—Same as Experiment 1, but 7·42 grains of calcium hydrate ($CaO$, $H_2O$) added. The initial *B. coli* determination was + o·o1 c.c. After twelve hours, a little of the clear liquid was drawn off and the excess lime was found to be 4·0. After shaking, *B. coli* cultures were made and no *B. coli* were found, even in 100 c.c. 1·5 grains of sodium bicarbonate were next added to 20 ounces of the mixture, together with a trace of sodium carbonate to ensure the softening effect. After settlement, the hardness was again determined and found to be 2·5 grains per gallon.

*Experiment* 3.—Same as Experiment 1, but 6·42 grains of calcium hydrate ($CaO$, $H_2O$) added. The initial *B. coli* determination was + o·o1 c.c. After twelve hours, a little of the clear liquid was drawn off and the excess lime was found to be 2·8. After shaking, *B. coli* cultures were made and no *B. coli* were found, even in 100 c.c. 1·05 grains of sodium bicarbonate were next added to 20 ounces of the mixture, and after settlement the hardness was determined and found to be 2·7. The chief results may be tabulated as follows:—

TABLE XIX.—HARD WELL-WATER. LIME AND SODIUM BICARBONATE
METHOD. TOTAL HARDNESS 23 (PERMANENT HARDNESS 6·4) GRAINS
PER GALLON.

| Experi-ment | Initial *B. coli* result | Excess lime (CaO) in grains per gallon | Final *B. coli* result, after twelve hours' contact | Final total hardness, in grains per gallon |
|---|---|---|---|---|
| 1 | + 0·1 c.c. | 0·9 | − 100 c.c. | 6·3 (nearly 73 per cent. reduction) |
| 2 | + 0·01 c.c. | 4·0 | ,, | 2·5 (about 89 per cent. reduction) |
| 3 | ,, | 2·8 | ,, | 2·7 (about 88 per cent. reduction) |

It will be noted that even so small an excess as 0·9 of lime (CaO) proved effective, although, in practice, it would hardly be safe to rely on so small a dose in the absence of skilled supervision and the application of frequent bacteriological tests. More-over, in cases where there is a fair amount of permanent hardness there is no good reason for running things too fine, because more lime simply means more bicarbonate of soda, greater security and a beautifully soft water as the final product.

## SERIES IX.

### *Miscellaneous Experiments.*

*Experiment* 1.—An impure river-water in flood (initial colour 208, initial hardness 20·7, initial *B. coli* result + 0·1 c.c.) was treated as follows: Three parts were heated and brought barely to the boiling point and then added to one part, which

was not heated. After five minutes, cultures were made and no *B. coli* were present, even in 100 c.c. of water. Some of the remaining water was treated with aluminium sulphate (in the proportion of 6 grains per gallon); after settlement, the colour was 44 (nearly 79 per cent. reduction) and the hardness 21·9.

*Experiment* 2.—Same as Experiment 1, except that clarification by aluminium sulphate was not tried and the sample was collected on a different date. Initial *B. coli* result + 0·01 c.c. Final *B. coli* result negative 100 c.c. These two experiments show that by adding three parts of "boiled" to one part of "unboiled" water, the mixture is rendered perfectly safe to drink. In Experiment 1, it is also shown that aluminium sulphate has a powerful clarifying action.

*Experiment* 3.—A river-derived water having an average hardness of 19·4 grains per gallon was treated with calcium hydrate. The next day the clear liquid was decanted and the caustic alkalinity estimated. It was found to be 2·2. The hardness was also determined and found to be 7·7. No bacteriological tests were made, it being clear from the results of the experiments already recorded that this excess would suffice for sterilization purposes. Two ounces of the liquid were then placed in a small flask, phenol phthalein solution added, and "carbonic acid water," freshly drawn from a

sparklet syphon, very gradually run in by means of a graduated pipette, until the pink colour disappeared. Half the number of cubic centimetres of "carbonic acid water" required were next added for each 2 ounces of the lime-treated water. After the precipitate of carbonate of lime produced ($CO_2$ + CaO = $CaCO_3$) had settled, the hardness was re-determined and found to be 6·5.

*Experiment* 4. — This experiment was on all fours with Experiment 3. The excess lime (CaO) was 3·8, and the hardness 12·4. After neutralization with "carbonic acid water" the hardness was reduced to 6·0.

*Experiment* 5.—Same as Experiments 3 and 4. Excess lime (CaO) 3·6, hardness 11·7. After neutralization with the "carbonic acid water" the hardness was reduced to 6·2.

*Experiment* 6.—Same as Experiments 3, 4 and 5. Excess lime (CaO) 4·9, hardness 14·6. After neutralization the hardness was reduced to 7·2.

Experiments 3 to 6 show that if lime is used as a sterilizing agent, the excess CaO can be neutralized by means of "carbonic acid water" derived from a sparklet syphon or gasogene, the carbonate of lime produced being precipitated and the water "softened" in consequence. The volume of "carbonic acid water" required depends, of course, on the concentration of the carbonic acid gas in it and

the amount of excess lime (CaO). In the above experiments about 2·8 to 5·6 ounces were required per gallon.

It should perhaps be stated that in practically all these experiments comparatively small quantities were dealt with, and a cheap dispensing pair of scales were used for weighing purposes.

In conclusion, the chief points to be noted are as follows:—

Rain-water can be sterilized with very small doses of lime and the excess lime (CaO) neutralized by means of sodium phosphate.

Soft peaty moorland waters may be sterilized with lime (about 2 grains per gallon in excess) and the excess neutralized with aluminium sulphate; or else sterilized with chlorine (about 1 in 1 million).

Hard well-water is conveniently sterilized and softened by means of lime and sodium bicarbonate.

Sterilization can be effected by adding three parts of boiling water to one part of unboiled water.

"Carbonic acid water" can be used for neutralizing the excess lime (CaO) in a lime-sterilized water.

The concluding chapter deals with a description of the apparatus required for the sterilization of water on a domestic scale.

## CHAPTER VIII.

### DESCRIPTION OF APPARATUS (*see* Figs. 12 to 18).

The writer has assumed throughout a daily consumption for drinking purposes (per household) of ten gallons; where more is needed the tanks or vessels required may be correspondingly increased in size, and where less, provision has been made for more than one day's supply.

The tanks or vessels must be in duplicate so as to allow of their alternate use for purposes of treatment.

The 10 gallon glazed earthenware vessels known technically as " mixing pans " (*see* Fig. 12) serve admirably, for this purpose.

The tubulure is fitted with a perforated rubber bung, but the attachments depend very much on circumstances.

(a) *Floating Arm Method* (*see* Fig. 13).—Where it

is desired to draw off a very clear liquid, a glass tube
is inserted in the rubber bung.  At the distal (outlet)
end is a piece of rubber tubing, a strong pinch-cock
or screw clip (*see* Fig. 14) and another piece of
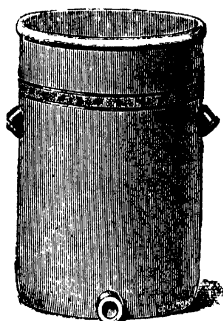


FIG. 12.
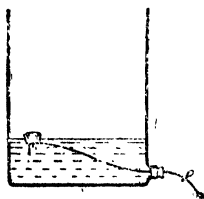


FIG. 13.—Floating arm method.                FIG. 14.
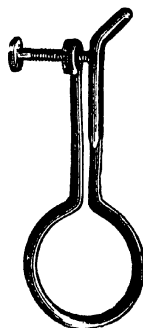
glass tubing, which, if thought necessary, may be
covered at its free end with one or more folds of
fine linen, bound on with a rubber band.  Alter-
natively, instead of a piece of plain glass tubing, a

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" thistle head " tube may be used and the interior packed with absorbent cotton wool or asbestos fibre, kept in place with a piece of linen stretched over the mouth and held in position with a rubber band (*see* Fig. 15).
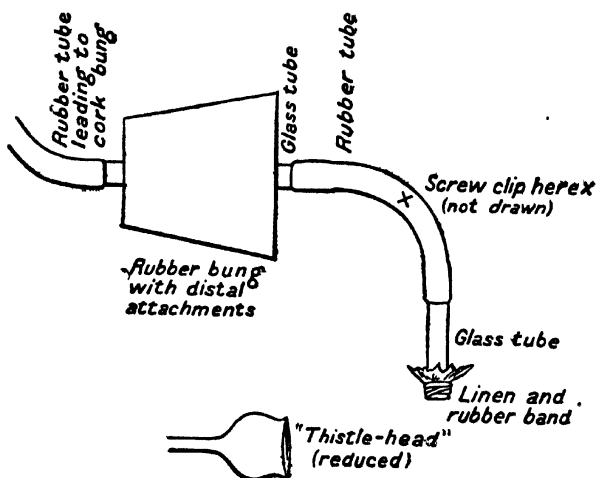


FIG. 15.—Rubber bung with its distal connections.

At the proximal end (inside) is a piece of rubber tubing nearly long enough to extend right across the vessel (*see* Fig. 13). Its free end is fixed firmly by means of a very long pin (say 2 inches long) to a large cork bung (say 2 to 3 inches in diameter) and it is desirable to stick into the bung two other pins, so as to provide three more or less equidistant legs (*see* Fig. 16). This allows the cork floater to rest

securely on the bottom, when the liquid has been drawn down to its lowest level, without disturbing the sediment. Next, the rubber tube is pinched and two or three holes cut out with sharp scissors at different angles close to the cork bung. Obviously,
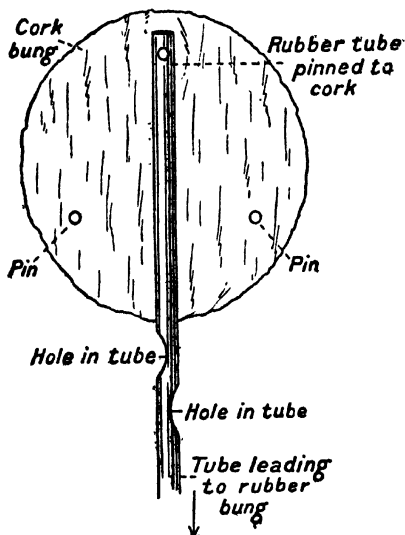


FIG. 16.—Cork floater.

when the vessel is filled with water the cork floats, and when the exit stopcock is opened the liquid escapes from near the surface through these holes. As the liquid falls in level so also does the cork, until finally the pins strike and rest on the bottom of the vessel and all the liquid excepting about the

last gallon (more or less, according to the length of the pins and the position of the holes) is withdrawn without disturbing the sediment.

(b) *Rigid Outlet Method.*—For all practical purposes it is sufficient to have a fixed "draw-off" slightly above the level of the precipitate (say ½ to 1 inch). The proximal end of the tube should not project inside the vessel as the precipitate settles on it, and at the very end of the "drawing-off" process, it is liable to be detached and sucked down the tube (*see* Fig. 17). The distal end of the
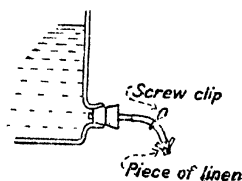


FIG. 17.—Rigid outlet method.

tube may, as in the "floating arm" method, be covered with linen or a thistle-head tube may be used, the interior being packed, if thought desirable, with absorbent cotton wool or asbestos fibre. Where the precipitate, *per se*, is absolutely harmless (e.g., a precipitate of carbonate of lime) these straining processes seem unnecessary, unless possibly on æsthetic grounds, and even in the case of alumina their use can hardly be considered at all essential, as practically all the precipitate is left at the bottom of

the vessel. ' In all purification processes it is a good thing to ask oneself the question : Is the mixture in the freshly prepared and stirred up condition injurious from the chemical point of view? If not, it is out of the question to regard the final product as a source of danger to health.

(c) *Filtration Methods.*—This book is concerned chiefly if not entirely, with non-filtration processes of water purification. This does not necessarily mean that the author has no faith in filters, but the subject of filtration has already been dealt with by numerous writers (e.g., Dr. Sims Woodhead). If, however, it is thought desirable to filter finally the sterilized liquid, the consumer must decide whether it is better to use one of the many patent filters on the market or to construct one himself.

· The writer does not propose to enter into a discussion of the respective merits of the different types of patent domestic filters, but only to indicate very briefly how a small filter may conveniently be constructed.

The mixing pans already described may be had in small sizes (one gallon). The tubulure is fitted with a rubber bung, and a bit of glass tubing to which is attached a piece of rubber tubing controlled by means of a screw clip (*see* Fig. 14). The bottom is filled with gravel varying in size from a bean to a very small pea, the coarse material being undermost. The gravel should extend well above the

level of the outlet tube, as otherwise the sand will
be sucked downwards and appear in the filtrate.
Next is placed a layer (say ½ inch) of coarse sand and
then fine sand on the top of this (say 2 to 3 inches).
The whole is then well covered with a layer of pea-
sized gravel to prevent the onflowing water from
disturbing the surface of the sand. It is essential
that the gravel and sand should be scrupulously
clean, and if any doubt exists as regards its purity,
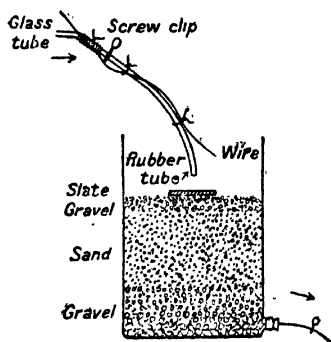


Fig. 18.—Small filter.

the filter should be filled with boiling water and the
outlet tube opened a little and more hot water poured
on to take its place, until the temperature of the
outgoing water is 70° C. and still rising. When
it is certain that the whole of the contents of the
filter has been exposed to this temperature, the
outlet tube may be closed and in five minutes the
filter may be safely assumed to be free from any of
the microbes causing epidemic disease, and the

water finally run off. It is a good plan to place a small piece of flat slate on the surface of the filter as the onflowing liquid impinging on it is spread over a larger area. It is desirable as well to alter from time to time the position of the slate and the delivery tube. As regards the latter, a piece of copper wire may be tied firmly on to the glass tube and the rubber tube fastened *loosely* to it as well. Then by bending the wire slightly the direction of the flow of water may be altered at will. When filtering, the outlet tube should be completely open and the rate of filtration controlled by the screw clip on the delivery tube. The speed of filtration may be made as slow as circumstances permit, but must never be so fast as to cause "ponding" on the surface of the filter with a consequent risk of an overflow. The first few ounces of filtrate should be rejected or poured back on to the surface of the filter. Once a week (or more frequently, if thought desirable), the bits of gravel should be removed from the surface of the gravel and also about half an inch of the top layers of sand. This is readily done by means of a little scoop—a bit of bent tin does well for this purpose. The sand and gravel should be washed separately, first in cold, and then in very hot water and replaced and any loss made good. About once a month it may be desirable to remove the whole of the material from the filter and replace it with fresh gravel and sand, or the same material after it has been thoroughly cleaned. It will be noted that this

is the "percolation" as opposed to the "submerged" method of filtration and it has the advantage of encouraging aeration. At the same time, such a filter may actually not achieve as good results as a dirty "mature" filter, the reason being that in the former case practically all the non-sporing bacteria have been banished, whereas in the latter case microbes are present in enormous numbers and some species exercise a purifying action on the water. In the present case, however, the water is supposed to be sterile to start with, and the filter is only required in order to remove the suspended matters from the water. Of course, any ingenious person can make a filter out of almost anything, e.g., a flower pot can be readily adapted for this purpose.

A few words must be said about the disposal of the precipitate left in the 10 gallon vessel. One way is to run the whole of it to waste. If this method is decided upon, a couple of wedge-shaped pieces of wood should be inserted laterally towards the side of the vessel farthest from the outlet. Next, a pail should be placed underneath the outlet, the precipitate well stirred up and the bung removed, so as to allow the contents to escape from the tilted vessel with a rush. Some more water may be used to flush out the residue, but this is hardly necessary in actual practice.

Another way is to leave the precipitate and supernatant water *in situ*, and make an allowance for its presence by adding fresh chemicals in reduced

amount to the next lot of water. This entails knowledge of its volume ; and this information is readily obtained either by measuring the amount drawn off and deducting it from the total, or ascertaining beforehand what volume of water the vessel holds up to the "draw-off" level. Within limits, the old precipitate rather helps in the production of a further deposit, but, of course, the time comes (say in a week) when the whole of the sludge must be swept out to waste. Generally speaking, the first method should be adopted in cases where an accumulation of the deposit is for some reason undesirable. On the other hand, where the precipitate is *per se* innocuous (e.g., carbonate of lime) the final flushing operation may be delayed for some considerable time.

The writer has not dealt so far with the vessel or vessels in which the purified liquid is to be collected, This obviously depends upon circumstances ; for example, if the whole of the water is required daily, it may be collected in one large vessel and the whole of the plant duplicated for use each alternate day. On the other hand, if only a small proportion is needed daily it may be convenient to fill a series of Winchester quart bottles (carefully dated) and delay the preparation of a fresh lot of purified water until their contents have been nearly exhausted. No one of intelligence can fail to find out by experience the method best adapted for his (or her) particular requirements. Needless to say the

vessels should be scrupulously clean, and if more than one day elapses between collection and consumption they should be glass stoppered.

When what may be described as the "long time lime" method of treatment (*see* Chapter II.) is adopted, duplicate tanks capable of holding, say seven days' supply, are provided. Here the dose of lime required is so small as not to need neutralization and the tanks may be drawn on, on alternate weeks, just when the water is actually needed. Galvanized iron tanks may be used for this purpose, the outlet pipe being placed laterally a few inches from the bottom. Another outlet pipe may be provided for periodical flushing out of the accumulated deposit, and this should preferably be placed on the actual bottom (i.e., facing upwards). In adding the lime, enough should be employed for the volume of water down to the level of the lateral outlet pipe, not for the total contents, which include, of course, the bottom water which is not drawn off, except occasionally. It is quite unnecessary to enter into any details as regards supports, height from the ground, &c., these being matters which the consumer is in the best position to deal with. When the foregoing method is adopted, it is assumed that the water is so reasonably clear to start with as not to require any filtration process. At the same time, there is no reason why the liquid drawn off from the large tank should not be filtered, if this· is thought desirable.

There is not much, if any real, objection to the use of chlorine as a sterilizing agent in connection with galvanized iron tanks. The zinc may be gradually dissolved, but, in the writer's opinion, the danger of zinc poisoning has been greatly exaggerated. The tanks could, of course, first be painted with " bituminous " or other suitable paint, but the water would be apt at first to have an appreciable taste. On the whole, however, the writer prefers lime to chlorine in those cases where it is proposed to reduce the dose of chemical to the lowest possible limit by greatly extending the period of contact, for the reason that the lime never ceases to act bactericidally until it is all carbonated, whereas the chlorine loses its effectiveness much more speedily.

·In conclusion, the chief points to be noted are as follows :—

The vessels or tanks and their connections required for the domestic purification of water may be of the simplest kind.

The method of working them presents no real difficulties.

If filtration is considered desirable, and a sand filter is preferred to a patent domestic filter, a home-made one is easily prepared, and readily kept sweet and clean.

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For the "long time lime" method of sterilization, galvanized iron tanks, holding, say seven days' supply, may be used.

### MISCELLANEOUS INFORMATION.

The following notes are meant for the non-expert reader.

The word *lime* is used by some persons to describe quicklime or calcium oxide ($CaO = 56$, sol. about 1 in 900)[1]; others apply it only to slaked ·lime, caustic lime, calcium hydroxide, or calcium hydrate ($CaO, H_2O = 74$); yet others use it in connection with calcium carbonate or carbonate of lime ($CaCO_3 = 100$). Chalk, whiting, marble, limestone, &c., are composed chiefly of carbonate of lime (sol. about 1 in 50,000).

*Calcium bicarbonate* or bicarbonate of lime ($CaCO_3, H_2CO_3 = 162$). The. chief cause of the temporary hardness of waters. Precipitated on boiling, or on addition of calcium hydrate.

*Carbonic acid gas* ($CO_2 = 44$). Occurs in water free as dissolved carbonic acid gas, or fully-bound (as, e.g., in carbonate of lime, $CaCO_3$), or half-bound (as, e.g., in bicarbonate of lime, $CaCO_3$, $H_2CO_3$). Can be used to precipitate calcium hydrate as calcium carbonate. If in excess it re-dissolves the carbonate to form the soluble bicarbonate of lime.

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[1] *See* Table XX, p. 117.

*Aluminium Sulphate* or sulphate of alumina ($Al_2(SO_4)_3$, 18 $H_2O$ = 666). Very soluble, forms a flocculent precipitate with alkalies, much used in the purification and clarification of waters.

*Sodium Carbonate* or carbonate of soda ($Na_2CO$ anhydrous = 106; $Na_2CO_3$, 10 $H_2O$ crystalline = 286). Very soluble, sometimes called "washing soda," frequently used for removing the permanent hardness of water due to sulphates, sodium sulphate being formed and the carbonates precipitated.

*Sodium Bicarbonate* or bicarbonate of soda ($NaHCO_3$ = 84). Very soluble, sometimes called "baking soda," can be used to precipitate calcium hydrate as calcium carbonate, sodium carbonate remaining in solution.

*Sodium Hydrogen Phosphate* ($Na_2HPO_4$, 12 $H_2O$ = 358). Very soluble, can be used to precipitate calcium hydrate as calcium phosphate.

*Phenol Phthalein Solution.*—A solution prepared by dissolving 0·2 gramme of phenol phthalein in 60 c.c. of alcohol (90 per cent.) and making up to 100 c.c. with distilled water. Used as an indicator; colourless in acid and bright pink in solutions of hydrates, and carbonates.

*Methyl Orange Solution.*—A solution prepared by dissolving 0·2 gramme of methyl orange in distilled water, adding 25 c.c. of alcohol (90 per cent.), and making up to 100 c.c. with distilled water.

Used as an indicator; yellow colour with alkalies and pinkish with acids.

*Potassium Iodide and Starch Solution.* — Rub 2 grammes of potato starch with enough distilled water to form a paste. Add 100 c.c. of distilled water and bring mixture gently to boiling point. Allow to settle, decant relatively clear liquid and . add two or three crystals of potassium iodide. Used to detect the presence of active chlorine, &c.

*Citric Acid* ($H_3C_6H_5O_7$, $H_2O$ = 208·5), *Tartaric acid* ($H_2C_4H_4O_6$ = 149) and diluted *Phosphoric acid* (B.P.) can be used to neutralize calcium hydrate.

These, together with the standard *lime* (1 c.c. = 0·001 gramme CaO), *sulphuric acid* (1 c.c. = 0·001 gramme CaO), and *soap* (1 c.c. = 1 degree of hardness), solutions may be obtained from any first class firm of chemical dealers employing well-trained chemists.

*Calcium Hypochlorite*, in the form of bleaching powder or chloride of lime. Should contain about 33 per cent. of available chlorine. A most powerful germicide.

"*Chloros*," a solution of sodium hypochlorite, containing about 12 to 15 per cent. of available chlorine. Used, like bleaching powder, for sterilizing impure water.

*Sodium sulphite* ($Na_2SO_3$, $7H_2O$ = 250), can be used as an "anti-chlor." (i.e., to remove any excess of active chlorine).

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## TABLE XX.—SYMBOLS AND ATOMIC WEIGHTS.

*Symbols and Atomic Weights of the Chief Elements mentioned in this Treatise.*

|  |  |  | Symbol |  | Atomic weight |
|---|---|---|---|---|---|
| Aluminium | ... | ... | Al | ... | 27 |
| Calcium... | ... | ... | Ca | ... | 40 |
| Carbon ... | ... | ... | C | ... | 12 |
| Chlorine | ... | ... | Cl | ... | 35 |
| Hydrogen | ... | ... | H | ... | 1 |
| Iodine ... | ... | ... | I | ... | 126 |
| Magnesium | ... | ... | Mg | ... | 24 |
| Manganese | ... | ... | Mn | ... | 55 |
| Nitrogen | ... | ... | N | ... | 14 |
| Oxygen ... | ... | ... | O | ... | 16 |
| Phosphorus | ... | ... | P | ... | 31 |
| Potassium | ... | ... | K | ... | 39 |
| Sodium ... | ... | ... | Na | ... | 23 |
| Sulphur ... | ... | ... | S | ... | 32 |

## TABLE XXI.—WEIGHTS AND MEASURES.

17 minims = 1 cubic centimetre

About 15 grains = 1 gramme

1 gallon = 10 lb. = 70,000 grains = 160 ounces = 4546 cubic centimetres

### FLUID MEASURES.

1 fluid drachm = 60 minims = 54·68 grains (3·552 c.c.)

8 fluid drachms = 1 fluid ounce

20 fluid ounces  = 1 pint

2 pints = 1 quart

4 quarts = 1 gallon (160 ounces)

### SOLID WEIGHTS.

1 cwt. = 112 lb.   1 ton = 2240 lb.

About 109 grains = $\frac{1}{4}$ ounce

About 219 grains = $\frac{1}{2}$ ounce

About 328 grains = $\frac{3}{4}$ ounce

About 437 grains = 1 ounce

1750 grains = $\frac{1}{4}$ lb. = 4 ounces

3500 grains = $\frac{1}{2}$ lb. = 8 ounces

5250 grains = $\frac{3}{4}$ lb. = 12 ounces

7000 grains = 1 lb. = 16 ounces

The above notes relate to the avoirdupois or imperial standard weights and measures and they must not be confused with apothecaries' weight.

In the apothecaries' weight :—

### TABLE XXII.—APOTHECARIES' WEIGHTS.

20 grains = 1 scruple
3 scruples (60 grains) = 1 drachm
8 drachms (480 grains) = 1 apoth. ounce
(Note that the Imperial ounce = 437·5 grains.)

When working with *liquids* in small amounts, use measures divided into fluid drachms (8 to the fluid ounce) and minims (60 to the fluid drachm). For *larger* amounts work with the pint (20 ounces), quart (2 pints = 40 ounces), or gallon (4 quarts = 160 ounces.)

It is to be hoped that the day is not far distant when we shall finally adopt the simple and scientific way of measuring liquids in terms of litres and cubic centimetres. In all scientific laboratories the International system (both for weights and measures) has been in vogue for many years.

When dealing with weights in small amount, the weights (apothecaries') will be in grains, scruples, (20 grains), and drachms (60 grains), and the ordinary apothecaries' scales may be used.

For heavier weights, use the imperial ounce (437·5 grains) or its fraction (letter-weight balance), and pound (16 ounces, 7,000 grains), or its fractions (kitchen balance). Of course, the different balances and their weights encroach, so to speak, on each

other, but, generally speaking, the kitchen balance should not be used below $\frac{1}{4}$ lb. and the letter-weight balance below $\frac{1}{4}$ ounce.

## CONVERSIONS.

Grammes (or cubic centimetres) into grains, ounces or pounds, multiply by 15·432, 0·03528 and 0·0022046 respectively.

Grains, ounces or pounds into grammes (or cubic centimetres), multiply by 0·0648, 28·35 and 453·6 respectively.

Degrees Centigrade into degrees Fahrenheit, multiply by 9, divide by 5, and add 32.

Degrees Fahrenheit into degrees Centigrade, subtract 32, multiply by 5 and divide by 9.

Parts per 100,000 into grains per gallon, multiply by 7 and divide by 10.

Grains per gallon into parts per 100,000, multiply by 10 and divide by 7.

" Hardness " parts per 100,000 ($CaCO_3$) into degrees of hardness = Clark's scale = grains per gallon, multiply by 7 and divide by 10.

Grains into scruples (apothecaries'), drachms (apothecaries'), ounces (imperial), and pounds (imperial), divide by 20, 60, 437·5, and 7,000 respectively.

Scruples (apothecaries') into drachms (apothecaries'), ounces (imperial), and pounds (imperial), divide by 3, 21·875 (say, 21·9), and 350 respectively.

Drachms (apothecaries') into ounces (imperial) and pounds (imperial), divide by 7·29167 (say, 7·3), and 116·667 (say, 116·7) respectively.

Ounces (imperial) into pounds (imperial), divide by 16.

All these little difficulties may be overcome by the purchase of a set of weights from 10,000 grains down to 1/10 grain. Their use renders it unnecessary to consider the " grain value " of scruples, drachms and ounces (apothecaries' weights), and ounces and pounds (imperial weights). The weights are arranged in the simple and scientific manner pertaining to the gramme weight (and its multiples and fractions), which apparently only our insular prejudice prevents us from finally adopting.

Capacity in gallons of rectangular vessels: Multiply length by breadth, by depth in inches, and divide by 277·5.

Capacity in gallons of cylindrical vessels: Square of half the diameter in inches multipled by 3·1416; multiply product by depth in inches; divide answer by 277·5.

### EXCESS LIME (CaO) METHOD.

Each grain per gallon of excess lime (CaO) requires for its neutralization—

Sodium hydrogen phosphate 4·26 grains (2 grains of sodium bicarbonate subsequently added to form sodium carbonate), or—

Aluminium sulphate crystals 3·96 grains (5·11 grains of sodium carbonate crystals subsequently added (*see*, however, p. 25) to precipitate the sulphates + an extra 2·86 grains for every degree of permanent hardness in the water before treatment), or—

Sodium bicarbonate, 3 grains, or—

"Carbonic acid water." Half the amount required to remove the pink colour from a known amount of the lime-treated water to which phenol phthalein has been added, or—

Citric acid, 1·24 grains, or—

Tartaric acid, 2·66 grains.

All these substances are very soluble (sodium bicarbonate much less soluble) and may be added, if preferred, as solutions. One fluid ounce would be the correct dose for 10 gallons, if the foregoing figures are in each case multiplied by 800 and that amount dissolved in 80 ounces (1 Winchester quart or ½ gallon) of water. Hot water may be used to accelerate solution, except in the case of sodium bicarbonate, which unfortunately is the least soluble of those specified.

Dose of *excess* lime (CaO) for sterilization purposes. About 3 grains (*excess* CaO) per gallon with about twelve hours' contact, but a good deal

depends upon the quality of water being dealt with.

Generally speaking, this is considerably in excess of the dose actually required, but in these matters it is well to err on the side of safety. Given several days' contact the dose may be reduced to a fraction of 1 grain, and even with only twelve hours' contact 1 to 2 grains may suffice, but in these cases skilled estimations of the actual excess of · lime (CaO) and frequent bacteriological tests are desirable. Only an expert can be trusted to sterilize a water with the absolute minimum dose.[1]

Dose of *Chlorine* for sterilization purposes, in terms of available chlorine. About 0·07 and 0·0234 grain per gallon according to the quality of the water to be treated, with about twelve hours' contact. In terms of actual materials (bleaching powder and chloros), multiply by 3 and 8 respectively.

## COST OF CHEMICALS, APPARATUS, &c.

The *pre-war retail* prices of the chief chemicals, apparatus, &c., mentioned are taken from well-known dealers' price lists. (See Table XXIII.)

. Of course, the price of these reagents varies greatly according to their degree of purity, and all of them, if bought in larger quantities, would cost far less.

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[1] For amount of lime, as *slaked* lime, *see* pp. 19, 30, 33, 34.

The price of the standard sulphuric acid, lime water, and soap solution would be about 1s., 1s. and 2s. 3d. a lb. respectively.

The phenol phthalein and methyl orange solutions would each cost about 5d. an ounce.

The potassium iodide and starch solution would cost about 2s. 6d. a lb.

TABLE XXIII.—TABLE OF COSTS.

| | | | Per lb. (7,000 grains) |
|---|---|---|---|
| Sodium phosphate (crystals) | ... | ... | 8d. |
| „ carbonate „ | ... | ... | 6d. |
| „ bicarbonate (powder) | ... | ... | 6d. |
| Citric acid (crystals) ... | ... | ... | 1s. 9d. |
| Tartaric acid „ ... | ... | ... | 1s. 6d. |
| Bleaching powder (in tins) ... | ... | ... | 5d. |
| Calcium hydrate ... ... | ... | ... | 4d. |
| Aluminium sulphate (crystals) | ... | ... | 2s. 3d. |
| Wood charcoal[1] (powder) ... | ... | ... | 5d. |

Dispensing hand scales (with weights, 2 drachms to $\frac{1}{2}$ grain) cost about 5s. to 7s. 6d.

A better and more delicate dispensing balance (nominally sensitive to $\frac{1}{10}$ grain) costs about 16s. 6d. to 25s.

Letter-weight and kitchen balances are (at all events the latter) household necessities. Their price varies greatly, according to quality, but is comparatively small.

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[1] Wood charcoal can be prepared quite easily at home. Fill an empty tobacco tin (or any other convenient tin) with bits of ordinary firewood. If the lid fits very tightly, bore one or two *small* holes through the tin. Place on a red fire. The escaping gases will catch fire and burn, but after a time this action ceases, and the tin becomes red hot. Leave for a little longer and then remove tin and set it aside to cool.

A cheap burette stand (to hold two burettes) costs about 2s. 9d.

50 c.c. burettes cost 3s. 6d. to 5s. each.

The necessary small flasks, bottles, &c., cost only a few pence each.

The 10-gallon and 1-gallon mixing pans cost about 22s. and 3s. respectively.

Galvanized iron tanks holding 10, 25, 50, 75 and 100 gallons cost about 12s., 12s. 6d., 17s., 20s., and 25s. respectively.

The following useful practical notes (with plan) on the *Utilization of Rain-water for Domestic Purposes*, taken from pp. 22 to 25 of Kershaw's Book on "Sewage Purification and Disposal," are of interest from many points of view :—

"It may not be out of place at this point to refer briefly to rain-water collected from the roofs of cottages and out-buildings as a drinking water supply for places where water is scarce. It seems strange that this source of water supply is not more frequently utilized in England. In Bermuda (pop. in 1907, 21,000; rainfall about 48 in. p.a.) the only water supply is obtained from the rainfall falling on roofs and specially constructed " catches," from which it flows into large tanks cut out of the limestone and rendered with Portland cement. All roofs of dwelling-houses have an inclined fillet of cement running round them to collect the rain falling on them at one point. Unfortunately, the water is seldom filtered. Fig. 19 shows a plan and
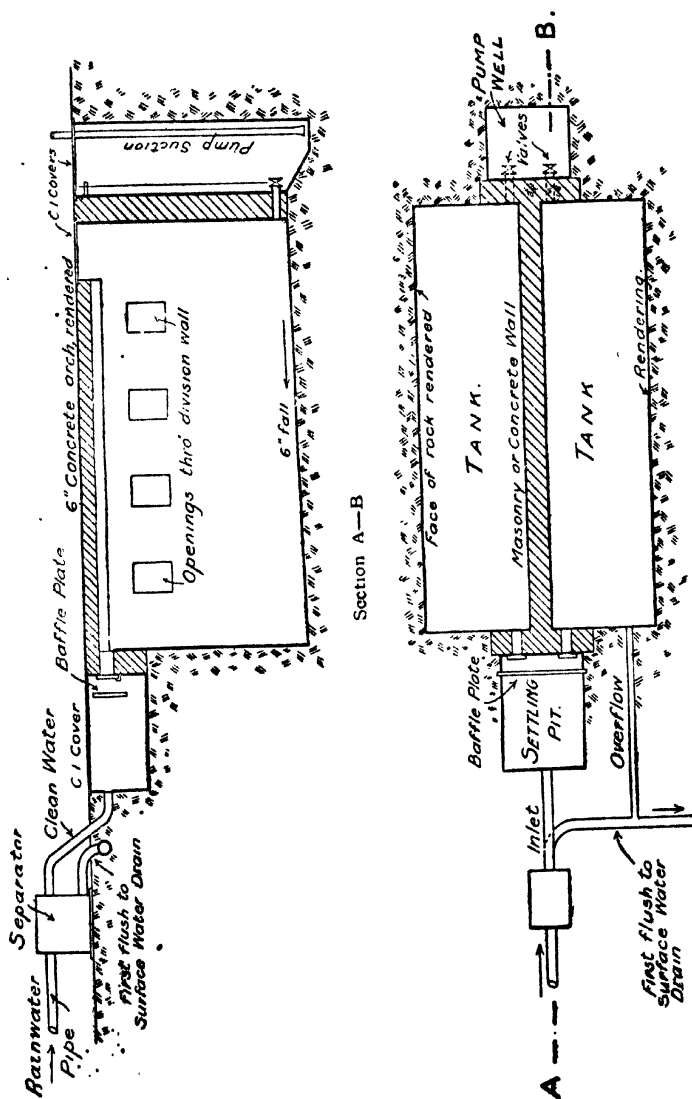
Section A—B

Plan

Fig. 19.—Plan of Rain-water Tank. (Kershaw.)

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. section of a rain-water tank constructed by excavation in rock, the walls and floors being rendered."

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"The following table (taken from *Quantity Surveyors' Diary and Tables* (Metchim and Sons, Princes Street, London, S.W.) gives the run-off of rain from a roof having an area of 100 square feet with varying degrees of rainfall :—

TABLE XXIV.—SHOWING DAILY YIELD OF WATER FROM 100 SQUARE FEET OF ROOF WITH VARYING RAINFALL.

| Mean rainfall | Loss from evaporation | Requisite capacity of tank | Mean daily yield of water | Mean daily yield wettest year | Mean daily yield driest year |
|---|---|---|---|---|---|
| Inches | Per cent. | Cubic feet | Gallons | Gallons | Gallons |
| 20 | 25 | 52 | 2·1 | 3·3 | 1·6 |
| 25 | 20 | 67 | 2·8 | 3·7 | 1·9 |
| 30 | 20 | 72 | 3·4 | 4·7 | 2·2 |
| 35 | 20 | 77 | 3·9 | 5·5 | 2·5 |
| 40 | 15 | 83 | 4·8 | 6·1 | 3·6 |
| 45 | 15 | 85 | 5·5 | 7·1 | 4·3 |

"Thus, with a roof area of 1,000 square feet, the mean daily yield in a district having an annual rainfall of 25 inches would be equivalent to 2·8 × 10 = 28 gallons.

"*Rain-water Separators.*—As the first washings from roofs generally contain soot, dust, bird droppings, decayed leaves, &c., it is advisable to turn to waste the first washings off the roof, before running the rain-water to the storage tank. To effect this, automatic contrivances termed Rain-water Separators have been devised : that form

known as the 'Roberts' separator, made by Rogers, of Haslemere, being perhaps as well known as any.

" These separators are guaranteed to take a rainfall at the rate of 2 inches per hour, and to work with a rainfall of $\frac{1}{2}$ inch per twenty-four hours on the areas given in the table below. In tropical countries where the rainfall sometimes exceeds 2 inches per hour, and in smoky cities, large separators are needed.

" It should be remembered that the separator must correspond to the size of the roof if it is to work properly.

TABLE XXV.—GIVING PARTICULARS OF RAIN-WATER SEPARATORS.

| | Area of roof in square feet | | Distance between the levels of inlet and outlet pipes | | Free to any railway station in Great Britain | | |
|---|---|---|---|---|---|---|---|
| No. | In the country | In the city or tropics | Pure outlet | Foul outlet | £ | s. | d. |
| | | | Inches | Inches | | | |
| I | 600 to 1,000 ... | — ... | $4\frac{1}{2}$ ... | II ... | 3 | 0 | 0 |
| 3 | 1,000 ,, 3,000 ... | 700 to 2,000 ... | 6 ... | 13 ... | 4 | 10 | 0 |
| 5 | 3,000 ,, 5,000 ... | 2,000 ,, 4,000 ... | 7 ... | $13\frac{1}{2}$ ... | 6 | 0 | 0 |
| 7 | 5,000 ,, 7,000 ... | 4,000 ,, 6,000 ... | 8 ... | 15 ... | 7 | 10 | 0 |
| 9 | 7,000 ,, 9,000 ... | 6,000 ,, 8,000 ... | 9 ... | $15\frac{1}{2}$ ... | 9 | 0 | 0 |
| II | 9,000 ,, 11,000 ... | 8,000 ,, 10,000 ... | 10 ... | 16 ... | 10 | 10 | 0 |

" Each further increase of 2,000 square feet in area of roof adds 30s. to the cost. The makers observe that the separators need no attention except washing out at intervals of about three months in the country and one month in town.

" With regard to the construction, size, and position of the storage tank, this should be constructed of cement concrete, or brickwork in cement with

excess manholes, and placed underground for reasons of temperature. According to the makers of the separators, it should be capable of holding a rainfall of about 4 inches, or, say, 1 cubic foot for each three superficial feet of roof, so that for a roof having an area of about 2,000 square feet the storage tank should hold 666 cubic feet or about 4,150 gallons; a larger capacity is desirable, however, if it can be obtained, but much depends upon what purposes the water is used for. In the case of most houses a tank holding 100 days' supply would be 'drought-proof.' The water before being used for drinking purposes should be passed through an efficient filter.

"There is no question that many rural districts might make far more use of rain-water for domestic purposes than is now the case."

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In this brief account of Rural Water Supplies and their Purification the Author has doubtless failed in many particulars, but if the reader cares to write and explain his (or her) difficulties, or to offer any suggestions or criticisms, the Author will endeavour to answer any such communications to the best of his ability.

A. C. HOUSTON,

19, Fairhazel Gardens,
London, N W.

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